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Northern
Plains Area

Natural Resources Research Center

1991 Report

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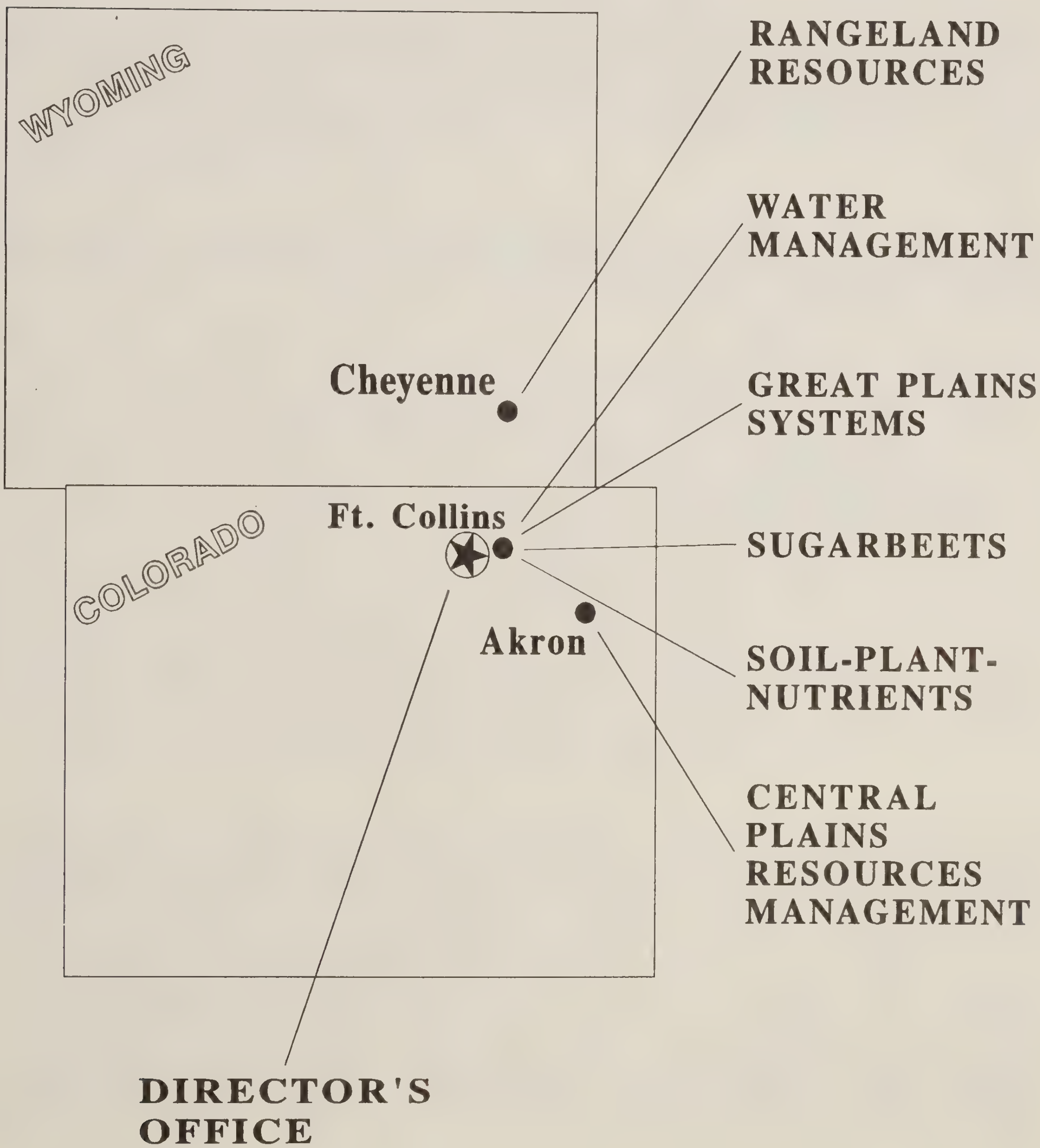
NATURAL RESOURCES RESEARCH CENTER



EXECUTIVE SUMMARY

James R. Welsh

The Natural Resources Research Center, formed in 1991, had an extremely productive year based on the six research units output. This report summarizes the activities and productivity developed and produced in 1991.

The most valuable output in any research program is newly generated information shared with scientific colleagues, technology transfer agents, and users. The NRRC scientists produced over 200 information documents ranging from articles in international peer reviewed journals items in the popular press. Individual NRRC scientists play key leadership roles in international conferences and symposiums, both in developing the conferences and presenting invited papers. Documentation of this activity is provided in the publications section of this report.

A second measure of excellence is recognition through national awards programs. Several NRRC scientists were given important awards by professional organizations and international societies. The awards and recognition section of this report provides detail in this testimony to professional excellence.

A third measure of excellence is centered on the ability to attract additional resources based on competence and program output. NRRC Units and individual scientists have played key leadership roles in the global change and water quality initiatives and have received support from ARS and other agencies in carrying out these activities. Approximately $1 million in additional ARS appropriations, specifically targeted to these special initiatives, have been allocated to NRRC units. In addition, NRRC units have been a major force in the consideration of other agency program relocations in the Fort Collins area. In particular, the Soil Conservation Service has chosen to relocate its Technology Information Systems Division here in part because of the excellent capabilities of the ARS scientists in information management programs particularly in computer and geographic information systems technology. Also, the Terrestrial Ecosystems Regional Research Analysis (TERRA) project, a key multi-agency effort in global change, is being located at Fort Collins with strong ARS leadership through the NRRC. This is anticipated to be a multi-million dollar per year program uniquely designed as a partnership arrangement with numerous agencies and potential private industry partners. Finally, ARS and the NRRC is playing a key role in the development of a proposal for a multi-million dollar Federal R & D Center in cooperation with Colorado State University and other federal agencies located in the area.

A final test of research effectiveness rests with the component of information management called technology transfer. The NRRC units has been particularly active and aggressive in promoting the use, in a practical application context, of information generated from solid research programs. The Technology Resource Integrated Management (TRIM) program is an example of a partnership effort between ARS, the Colorado State University Extension Service, financial institutions, accounting organizations, and users in making research information available in agricultural management decision setting. Likewise, the Great Plains Agrisystems Project (GPAP), lead by the NRRC, has accepted the challenge of processing and packaging numerous diverse databases across the Great Plains to develop on-farm management decision support packages. This program utilizes unique capabilities among scientists, technology transfer agents, and users in dealing with highly complex management decisions based on sound scientific information. NRRC units have played a major role producing and distributing programs

that will provide major impact in water quality and quantity management decision packages. Unique partnerships have been established between NRRC scientists and private industry in developing computer aided management options for on-farm use in pressurized irrigation systems. Our scientists recognize the value of feedback loops in the technology transfer area as an excellent mechanism to identify knowledge gaps and initiate research to fill critical needs.

In summary, the NRRC scientists and support staff had an outstanding 1991. This was accomplished even while Center restructuring was taking place. We anticipate that 1992 will be even more productive in all areas of research and leadership. This anticipated productivity is predicated on the proposition that the NRRC is composed of a group of outstanding scientists dedicated to improving science and agriculture locally, nationally, and internationally.

MISSION STATEMENTS

Natural Resources Research Center:

Deliver a coordinated research program providing scientifically sound information to improve agriculture systems regionally and nationally.

Central Plains Resources Management Research Unit:

Develop integrated cropping systems and crop production schemes for maximum utilization of soil and water resources while conserving them and protecting the environment. Emphasis is on efficient use of fertilizers, pesticides and water.

Great Plains Systems Research Unit:

Understand the effects of alternative management practices and global change on agricultural production and the environment with special emphasis on water quality. Develop integrated models of soil-water-plant-atmosphere continuum within agriculture as tools to enhance knowledge and improve technology transfer.

Rangeland Resources Research Unit:

Understand the interrelations of the basic resources that comprise rangeland resources. Develop science and technology that contribute to sustainable, productive rangelands in the Central Great Plains.

Soil-Plant-Nutrient Research Unit:

Develop and evaluate new knowledge required to efficiently manage soil, fertilizer and plant nutrients (emphasis on nitrogen) to achieve optimum crop yields, maximize form profitability, maintain environmental quality, and sustain long-term productivity.

Sugarbeet Research Unit:

Modify host-pathogen relations that affect disease resistance, pathogenesis, and epidemilolgy in sugarbeet and other crops. Identify and isolate genotypes exhibiting superior disease and stress tolerance and hybrid vigor.

Water Management Research Unit:

Develop systems for improved design and operation of pressurized and surface irrigation systems. Develop computer simulation models and expert systems to aid in the transfer of new technology and applied research.

NRRC Staff - 1991

James Welsh, Center Director
Olga Lee, Secretary

	Central Plains Resources Management Research Unit	Great Plains Systems Research Unit	Rangeland Resources Research Unit	Soil-Plant-Nutrient Research Unit	Sugarbeet Research Unit	Water Management Research Unit
Research Scientists	Ardell Halvorson, RL Randy Anderson Rudy Bowman Steven Hinkle David Nielsen Merle Vigil	Lajpat Ahuja, RL Carlos Alonso Vernon Cole Donn DeCoursey Jonathan Hanson David Hartley Marvin Shaffer	Gerald Schuman, RL Terrence Booth James Forwood Gary Frasier Richard Hart Jack Morgan Charley Townsend	Ronald Follett, RL Kevin Bronson William Hunter Gordon Hutchinson Arvin Mosier Lynn Porter Jean Reeder	Richard Hecker, RL Susan Martin Earl Ruppel	Dale Heermann, RL Walter Bausch Gerald Buchleiter Harold Duke Gordon Kruse Roger Smith Edward Schweizer
Support Scientists	William Beard Curtis Reule	Gerald Anderson Barry Baker Patricia Bartling Joseph Benjamin Virginia Ferreira Gregory McMaster	Daniel LeCain Ernest Taylor	Robert Lober William O'Dean	Judy Narum	Richard Miskimins Paul Williams Kristine Stahl
Post Docs		Romelito Lapitan Bruce Wylie	Andrew Lenssen John Reed	Kevin Bronson		Lori Wiles
Research Support Staff	Robert Florian Donna Fritzler Herman Horner Hubert Lagae Arnold Page Gene Uhler	William Dailey Debora Edmunds Terry Leonard Michael Murphy Harriet Rector Kenneth Rojas Lucretia Sherrod	Willard Ackerman Mary Calvert George Chavez Stanley Clapp Myrtle Engel Robert Engel Pamela Freeman Larry Griffith Jan Hagen Roger Kerbs Christopher Mahelona Dennis Mueller James Pry Kenneth Scott Jeffrey Thomas Barry Weaver	Charles Andre Cathy Booth Edward Buenger Susan Crookall Douglas Kirk Robin Montenieri Elizabeth Pruessner Mary Smith David Valentine	Christina Andre Mary McClintock Patricia Mustain Andrea Ragan Les Shader John Vasquez Bradley Wickham	Douglas Barlin Theodore Bernard Michael Blue Mark Collins Jonathan Jordan Gregory Larson
Administrative Support Staff	Ginger Allen Linda Pieper	Virginia Krug Marlene Miller Sharyl Rogers	Ann Flores Susan Moreau Kathleen Peterson Regina Wolf	Stacey Wilkins		Maxine McCauley
Visiting Scientists/ Others		Tom Hodges Francis Pierce	Li Aiguo Mike Hill Monica Martin Marvin Shoop John Waddington	Leif Klemedtsson		

PROGRESS REPORTS

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NRRC DEVELOPMENT AND ACTIVITIES

James R. Welsh
Natural Resources Research Center

NRRC FORMATION:

The Natural Resources Research Center (NRRC) was officially formed May 19, 1991. The NRRC has administrative and programmatic responsibility for the six research units contained in this report. In the restructuring process, seven original units were redesigned and staffed to form six units oriented to deal with natural resource issues locally, regionally, and nationally. The following outline shows the general restructuring and staffing:

Central Plains Resources Management Research Unit: (Ardell Halvorson, RL)
Dr. Rudy Bowman transferred in from Great Plains Systems and Dr. Wayne Guenzi transferred in from Soil-Plant-Nutrient. William Beard transferred in as a support scientist from Soil-Plant-Nutrient.

Great Plains Systems Research Unit: (Laj Ahuja, RL)
Dr. Laj Ahuja joined the Unit from Durant, Oklahoma and has subsequently been named Research Leader. Dr. Donn DeCoursey and Dr. Carlos Alonso transferred from the disbanded Hydrology Unit. Virginia Ferreira transferred into the Unit from Hydrology as a support scientist.

Hydrology:
This Unit was disbanded.

Rangeland Resources Research Unit : (Gerry Schuman, RL)
Drs. James Forwood, Gary Frasier, Jack Morgan, and Charley Townsend transferred in from Great Plains Systems. Dan LeCain transferred in as a support scientist from Great Plains Systems.

Soil-Plant-Nutrient Research Unit: (Ron Follett, RL)
Dr. Jean Reeder transferred in from Hydrology.

Sugarbeet Research Unit: (Richard Hecker, RL)
Dr. Ed Schweizer transferred to Water Management.

Water Management Research Unit: (Dale Heermann, RL)
Dr. Roger Smith transferred in from Hydrology and Dr. Ed Schweizer transferred in from Sugarbeets. Richard Miskimins transferred in as a support scientist from Hydrology.

PROJECTS:

Central Plains Experimental Range Advisory Committee: An advisory committee composed of ranchers, agricultural business men, and public agencies was formed to provide program guidance and support. A summer meeting and field day was held at the research station. The advisory committee has mounted a program to secure additional financial resources for the Range Program.

Central Great Plains Research Station Advisory Committee: This committee meets periodically to provide program guidance and support. In addition to the annual summer field day, the committee devotes part of each winter meeting to an open discussion on research priorities and directions. This input is used by the Central Plains Resources Management Research Unit and the NRRC in determining research needs. The committee has been instrumental in developing a proposal to increase cropping systems research support by $1.47 million per year for 8 years. This increase in support would include cooperative research with the Nebraska, Kansas, and Colorado State Experiment Stations.

Great Plains Agrisystems Project (GPAP): The NRRC has taken the leadership in developing a project to integrate research information across the Great Plains into farm and ranch level decision support systems. This project is the result of workshops involving research, technology transfer, and user leaders. The project will utilize electronic technology to manage large and diverse databases developed by the research community to deal with Great Plains agriculture issues.

Technology Resource Integration Management (TRIM): NRRC played a leadership role developing the TRIM project devoted to technology transfer at the farm level. This project is a cooperative activity with the Logan County Extension Service and was stimulated in part by user requests for improved technology transfer. The project will involve approximately 10 producers to be assisted by a facilitator in considering alternative management practices having the potential to increase profitability. A board of directors involving ARS, CSU, Agricultural Experiment Station and Extension Service, Northern Junior College, banking and accounting, and producers will guide and direct the project. This project has been partially financed by the Area Office.

Economic Analysis Project: An economic analysis thrust has been developed to determine potential economic impacts of alternate cropping systems in the great plains. The project under the direction of Dr. Ray Anderson, retired ERS, will develop economic budgets for alternative cropping systems based on long-term data from Central Plains Resources Management Research Unit and cropping systems research developed jointly by Dr. Gary Peterson, CSU Agronomy, and ARS. The analysis will consider current pricing values for inputs, farm program impacts, and other financial considerations affecting management decisions.

Terrestrial Ecosystem Regional Research Analysis (TERRA): The NRRC has been designated as the lead organization for the ARS component of the TERRA project supported by global change funds. TERRA will be a multi-agency project with the initial core team from ARS, USGS, and FS. The project will be headquartered in Fort Collins and will have as its focus the terrestrial components of global change. ARS has a particular interest in this project from the standpoint of agricultural interaction in global change.

Long-Term Ecological Research (LTER): This is a 5-year CSU/ARS project funded by NSF. The NRRC Director serves as co-PI on the LTER project. Members of the LTER program work closely with the Rangeland Resources Research Unit in numerous ecology oriented natural resource activities. Much of the LTER work is conducted on the Central Plains Experimental Range.

ACTIVITIES:

The NRRC hosted a visit by Director Dean Plowman and provided the form for an overview of the NRRC units and their research programs.

The NRRC has interacted extensively with the Soil Conservation Service in program planning and development. The NRRC units presented a day-long program at the annual Colorado Conservation District Meeting in Grand Junction. An important part of this meeting was a dialog with SCS staff and conservation district members regarding high priority research needs. This information has subsequently been used to identify those areas needing further research attention within the ARS program. A Memorandum of Understanding is being developed with SCS and the Colorado Association of Conservation Districts to establish an on-going dialog regarding research needs and technology transfer mechanisms.

A monthly research leader meeting schedule has been established to discuss and develop strategies to deal with high priority items affecting NRRC unit programs.

POST-DOCTORAL RESEARCH ASSOCIATE PROGRAM: NRRC units have been extremely successful in securing post-doctoral research associates funded in part through ARS headquarters. The Units currently have six post-doctorals on board. This strategy is viewed as extremely helpful in developing scientific capabilities as well as generating valuable research information.

CENTRAL PLAINS RESOURCES MANAGEMENT RESEARCH UNIT

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EFFECT OF CROPPING ROTATIONS AND TILLAGE ON EMERGENCE OF JOINTED GOATGRASS AND DOWNY BROME

R. L. Anderson and D. C. Nielsen
Central Plains Resources Management Research Unit

CRIS: 5407-12130-002-00D

PROBLEM:

Before the development of herbicides, crop rotation was a vital component of weed management systems. In the Plains region, jointed goatgrass and downy brome are two difficult-to-control weeds infesting winter wheat with viable seed persisting in soil for up to five years. Rotations which include spring-planted crops lengthen the time between winter wheat crops. This allows the producers to minimize interference of jointed goatgrass and downy brome infestation within winter wheat. The weed seed population decreases in soil because the weed seed germinates or decays naturally before the winter wheat is planted. Success in reducing the weed seed population would be enhanced if producers could hasten germination of weed seeds in the soil during non-wheat years. Several cultural practices affect seed germination and longevity in soil. For example, tilling the soil stimulates germination, with the largest impact occurring with the initial tillage operation.

The choice of spring-planted crop may also affect the germination of these winter annual weeds in the fall of the crop season. For example, proso millet and sorghum canopies greatly inhibit volunteer winter wheat emergence. However, emergence within a corn canopy is not reduced to the same extent, indicating that the use of corn rather than proso millet or sorghum in the rotation may increase the rate of weed seed decline by germination. Wheat residues on the soil surface also increase the germination in all canopies, thus, a no-till system may enhance second-fall germination of these grass weeds. If spring-planted crop canopies affect germination of jointed goatgrass and downy brome, then producers can target their severely-infested sites for germination-enhancing canopies. Also, combining one timely tillage operation (to stimulate germination yet not bury the residue) with a selected crop canopy may greatly enhance weed seed germination without deleteriously affecting crop growth.

The objectives for this study are: 1) evaluate the effect of crop rotations and tillage on the longevity of jointed goatgrass and downy brome seed in the soil; 2) determine the effect of spring-planted crop canopies on fall emergence of jointed goatgrass and downy brome; and 3) correlate the emergence of jointed goatgrass and downy brome with soil temperature and moisture levels and develop a predictive model.

APPROACH:

Four crop canopy choices are being evaluated within 3-, 4-, and 5-year rotations. The rotations are wheat-canopy choices-fallow, wheat-corn-canopy choices-fallow, and wheat-corn-oats for forage-canopy choices-fallow. Two tillage systems are being compared: no-till and reduced till (one sweep plow operation in the fall). The canopy and tillage treatments are arranged as a two-way factorial in a randomized complete block design with three replications. The rotations are arranged in a split-block design. Within each plot, 1 m^2 was designated and 200 seeds each of jointed goatgrass and downy brome spread on the soil surface. The tillage operation occurred after seed spreading. Winter wheat is present

within the local soil seed bank, but jointed goatgrass and downy brome had not been observed previously at this site. Seedling emergence is being recorded weekly for each 1 m^2 site for the duration of the study (5 years). There are 24 sites for each rotation (3 replications for each of the 4 canopies and 2 tillage treatments) and 3 rotations, resulting in 72 sites. After completion of the canopy choice cropping season within each rotation, winter wheat will be planted the following September. Weed seedling counts will also be recorded for each of the 24 sites from the previous 4 canopies and 2 tillage systems within the wheat crop (native seedbank sites). Soil samples will be collected from each site after wheat harvest to estimate the remaining weed seed population.

Within each canopy in 1991, 25 seeds of each species were planted in one-meter rows (planted sites). Simulated rainfall at 6 mm was applied after planting. Seedling counts were recorded 28 days later. Planting dates were Aug. 15, Sep. 1, Sep. 15, Oct. 1, Oct. 15, and Nov. 1. This treatment also will be repeated for each canopy site within each rotation during the year in which the canopy choices are established.

Soil temperature was monitored continuously with thermocouple arrays at 2.5 cm. Gravimetric soil water content was measured biweekly for the top 5 cm. Standard weed control practices were followed for each crop. Leaf area index was measured weekly.

FINDINGS:

Weed counts from August 30, 1991, until December 1, 1991 showed the effect of one fall tillage operation on seedling emergence. Emergence of volunteer wheat, jointed goatgrass, and downy brome were increased 109%, 79%, and 72%, respectively, when the soil was tilled once with the sweep plow (Table 1). The "soil water cost" for one tillage operation in the fall would be 5% less precipitation storage compared to a no-till fallow method. However, the reduced soil seed bank population would result in fewer weed plants infesting the following wheat crop. The emergence pattern and number were very similar between jointed goatgrass and downy brome. Emergence between August 1 and November 1 of 1991 was low, due to very little precipitation received during this time.

It appears that the barley stubble should be much more conducive to fall weed emergence than the corn and millet canopies due to the higher light levels at the soil surface and higher soil moisture contents following precipitation that occur following barley harvest. We speculate that we will see this higher level of weed emergence in the barley stubble compared with corn and millet canopies in falls with greater precipitation. The several August precipitation events that occurred in 1991 were not effective in germinating jointed goatgrass and downy brome due to the still very warm soil temperatures (weekly average $> 23°$ C)

Canopy microclimate affected the emergence of jointed goatgrass and downy brome in the planted sites, with corn = barley = fallow > proso millet in stimulating fall emergence of these species. These results are similar to previous research which showed that corn was conducive for fall emergence whereas proso millet reduced emergence. Barley offers another option for producers in devising alternative crop rotations for controlling jointed goatgrass and downy brome.

INTERPRETATION: If jointed goatgrass and downy brome are present in a field, producers should sweep plow once after winter wheat harvest to enhance seedling emergence and reduce the soil seed bank population. If a producer follows an alternative rotation scheme for winter annual grass control, corn

or barley should be the first crop grown after winter wheat. Proso millet imposes a microclimate that is not conducive for germination and emergence of either jointed goatgrass or downy brome. Therefore, producers should target proso millet for fields that are not infested with winter annual grass weeds.

FUTURE PLANS: Data will be collected for the duration of this study and published after statistical analysis.

Table 1. Seedling emergence response of volunteer winter wheat (VWW), jointed goatgrass (JGG), and downy brome (DB) to tillage in the native seedbank sites. Numbers represent seedlings that emerged between August 30, 1990, and December 1, 1991.

	VWW		JGG		DB	
	RT	NT	RT	NT	RT	NT
TIME INTERVAL	------------------(no./m^2)----------------					
SEP-NOV	313	121	64	36	63	3
DEC-FEB	0	0	0	0	0	0
MAR-MAY	9	6	2	1	1	1
JUN-AUG	35	43	1	1	1	1
SEP-NOV	0	0	0	0	0	0
TOTAL EMERGENCE	357*	170	67*	38	65*	38

RT: one sweep plow operation before residual herbicides were applied
NT: residual herbicides only for weed control during fallow

*indicates that the emergence totals within each species differ significantly between RT and NT treatments

CLOMAZONE (COMMAND) FOR CONTROL OF JOINTED GOATGRASS AND DOWNY BROME IN WINTER WHEAT

R. L. Anderson and Claude Ross
Central Plains Resources Management Research Unit

CRIS: 5407-12130-002-00D

PROBLEM: Jointed goatgrass and downy brome are severe weed problems in the winter wheat production area of the Great Plains region. Due to similar genetic and growth characteristics as winter wheat, herbicidal options for within-crop control of these species are very limited. In the Pacific Northwest, in-wheat applications of atrazine have been successful in controlling downy brome in winter wheat. Clomazone also shows potential for controlling both jointed goatgrass and downy brome with in-wheat applications, but phytotoxicity to winter wheat has occurred in some situations. The focus of this research is to explain why this phytotoxicity to winter wheat occurs in relation to cultural practices available to the producer and to identify the physical factors which will enhance clomazone bioactivity on jointed goatgrass and downy brome without injuring winter wheat. Specific objectives are: 1) determine the sensitivity of jointed goatgrass, downy brome, and winter wheat to clomazone in soil; 2) examine the effect of phorate (Thimet) on safening wheat to clomazone; and 3) determine the effect of precipitation timing and amount and growth stage on species response to clomazone.

APPROACH:

Greenhouse study: Sensitivity of jointed goatgrass, downy brome, and two winter wheat varieties (Tam 107 and Lamar) to five concentrations of clomazone (5, 10, 20, 30, and 40 ng a.i./mg) were determined in a silt loam and a sand soil. Eight seeds of each species were planted in treated soil and % chlorosis and above-ground biomass of all seedlings were determined 21 days after emergence for each species. The soil was maintained at 80% field capacity by daily watering to the soil surface, with the pots being weighed to determine the water level. The experimental design was a randomized complete block with 6 replications. Six seeds of each of the above species and varieties were planted at 0, 1, 2, 3, 4, and 5 cm below the soil surface in the silt loam. Clomazone at 0.28 kg/ha was applied to the soil surface, then water at simulated rainfall levels of 8 mm was applied to the clomazone-treated surface. After the initial watering treatment was applied, the pots were covered with tin foil for 4 days (allowing the seedlings to emerge), then water levels were maintained at 80% field capacity by daily weighing and subirrigating. Percent chlorosis and biomass measurements of all seedlings were taken 21 days after emergence.

Field study: Clomazone at 0.14, 0.28, and 0.56 kg/ha was applied at three times: preplant, preemergence, and postemergence (1-3 leaf stage) to 'Sandy' and 'Tam 200' winter wheat. Phorate at 6.8 g/1000 m of row was applied to half of the plots with the seed at planting. The site is located on a Weld silt loam. Six weeks after wheat emergence, % chlorosis was be assessed. Grain yield, biomass production, and yield components were determined at harvest. The experimental design was a split block factorial with clomazone rate and time of application and phorate application as the main factors. There were 4 replications. The varieties were planted adjacent to each other.

FINDINGS:

Greenhouse studies indicated that seed positioning offers potential for selectivity in controlling jointed goatgrass or downy brome in winter wheat. Downy brome is more sensitive to clomazone than jointed goatgrass. If jointed goatgrass is greater than 4 cm deep in the soil, clomazone will not control jointed goatgrass without killing winter wheat planted at a similar depth.

In the field study with 'Sandy' wheat, phorate reduced visual injury of wheat by clomazone, but this safening effect did not occur with grain yields. Also, phorate reduced grain yield 15% when banded with wheat and no clomazone was applied, demonstrating phytotoxicity to 'Sandy' wheat. A significant clomazone rate by time of application interaction occurred. Grain yields were reduced by 0.56 kg/ha of clomazone when applied preemergence and postemergence, and by 0.28 kg/ha of clomazone when applied postemergence. 'Sandy' wheat was tolerant to all rates of clomazone applied preplant. The postemergence applications demonstrate that clomazone has foliar entry, which results in more injury.

With 'Tam 200' wheat, phorate alone caused 36% yield loss, while clomazone also was more injurious to 'Tam 200' than to 'Sandy', indicating that varieties differ in their tolerance to these two pesticides. The only treatments that showed potential for weed control in 'Tam 200' were clomazone at 0.14 and 0.28 kg/ha applied preplant. However, yields still were reduced by 12 and 19%, respectively, when compared to the control.

With both varieties, the yield component affected most by clomazone was number of culms/m^2.

INTERPRETATION: Applying phorate did not increase winter wheat tolerance to clomazone. However, potential exists for applying clomazone alone for annual grass control in winter wheat if clomazone is applied preplant or preemergence at 0.14 or 0.28 kg/ha with 'Sandy' winter wheat. Varietal tolerance to clomazone differs. Seed position in relation to clomazone location in the soil will be a major factor affecting success of this control approach. This data also suggests possible cultural practices (such as maintaining a no-till system to keep weed seed on the soil surface, and to plant a more tolerant variety at a specified depth to reduce the wheat's exposure to clomazone) that the producer can used to enhance the potential for successful control of jointed goatgrass or downy brome with clomazone.

FUTURE PLANS: A new study was established near Platner in cooperation with CSU and Phil Westra. Two more varieties (Lamar and Scout) were added to the experiment. Greenhouse studies are exploring the seed positioning effect as related to rainfall levels and timing, and soil type.

TOLERANCE OF OATS, FOXTAIL MILLET, PROSO MILLET, AND SUNFLOWER TO CLOMAZONE (COMMAND) AND ATRAZINE

R. L. Anderson and D. J. Lyon
Central Plains Resources Management Research Unit

CRIS: 5407-12130-002-00D

PROBLEM:

With the development of more efficient methods for weed control during non-crop periods in the Central Great Plains, producers are cropping more intensively. Spring-planted crops such as corn, proso millet, and safflower have been successful in a winter wheat-spring-planted crop-fallow rotation. This two-crop-in-three-year rotation uses precipitation more efficiently in grain production, and also aids the producer from a pest management perspective.

Atrazine is the prevalent herbicide used for weed control in no-till fallow methods. Clomazone is also currently registered for use during fallow. Clomazone controls jointed goatgrass (Aegilops cylindrica Host) and downy brome (Bromus tectorum L.), weeds which atrazine is ineffective in controlling. Safflower, corn, and proso millet are tolerant of fall applications of clomazone, but producers are seeking other alternative crops to grow after winter wheat. Knowledge of crop options during a chemical fallow system would increase the flexibility producers have in selecting crop rotations. The objectives of this study are: 1) evaluate the biological response of oats, foxtail millet, proso millet, and sunflower to fall applications of clomazone and atrazine, 2) determine the duration of residual weed control by clomazone and atrazine within the crop canopies, and 3) compare the water use among these crops.

APPROACH: Clomazone and atrazine were applied on August 15, 1990, at 0, 0.5, and 1.1 kg/ha, alone and in all possible combinations, resulting in 9 treatments. The site was maintained as a no-till system. Oats, proso millet, foxtail millet, and sunflower were planted perpendicular to the herbicide treatments in the spring of 1991. The experimental design was a split block design with the crops planted in strips across the herbicide treatments which were arranged in a randomized complete block. There were four replications. Oats were planted in early April, and the millets and sunflower were planted in the first week of June. Planting rate for each crop was 70 kg/ha for oats, 12 kg/ha for both millets, and 50,000 plants/ha for sunflower. Ammonium nitrate was applied at 56 kg N/ha for oats and sunflower, and 36 kg N/ha for the millets. Herbicide injury to crops was assessed 3 and 6 weeks after planting by visual evaluations and biomass measurements. Residual in-crop weed control was assessed weekly. Forage yields were determined for oats and foxtail millet at the early milk and heading stage, respectively. Grain yields and biomass production of proso millet and sunflower were determined at maturity. Water use was measured gravimetrically before planting and after harvest for all crops.

FINDINGS:

Crop response to herbicides. The data summarized in this report are from the Akron site only. Visual symptoms were observed with oats only (clomazone causes a white bleaching of the leaves and atrazine causes a bronzing of the leaves with tip burning), with estimated injury being less than 5%. Visual symptoms did not occur with foxtail millet, proso millet, or sunflower. The herbicides did not affect productivity of any crop. Oats biomass production ranged from 5200 to 5900 kg/ha, while foxtail millet

produced 5000 to 5400 kg/ha of forage. Grain yields of proso millet ranged from 2650 to 3450 kg/ha. Total water use was 323, 217, and 222 mm for oats, foxtail millet, and proso millet, respectively.

Sunflower stands were very erratic due to rodent damage. Visual evaluations and biomass measurements of 3 plants per plot were taken at 28 and 42 days after emergence, but with the limited number of plants, grain yields were not determined at maturity. No visual herbicide symptoms on sunflower were observed, and biomass data also indicated that herbicide phytotoxicity did not occur with sunflower.

Weed control duration. All herbicide treatments controlled weeds during fallow until early June. At that time, all plots (except for the oats plots) were sprayed with paraquat before planting of foxtail millet, proso millet, and sunflower. The duration of weed control by clomazone and atrazine was similar to previous research conducted at the Akron station. No further within-crop weed control was applied for foxtail millet or proso millet, yet both crops were relatively weed-free at harvest. Precipitation was low after millet planting, thus allowing the crop canopies to develop before weeds emerged.

INTERPRETATION:: Producers applying clomazone + atrazine combinations for fallow weed control have flexibility in crop choice the following spring. In conjunction with previous research conducted at this station, this study demonstrates that corn, foxtail millet, proso millet, and sunflower can be grown after a clomazone-atrazine application the previous fall, without suffering crop injury. The advantage of combining clomazone and atrazine is increased control of jointed goatgrass and downy brome as compared to atrazine applied alone. This flexibility in crop choices enables the producer to maximize water use by crops while still controlling weeds during fallow and maintaining adequate residue levels on the soil surface for erosion control.

FUTURE PLANS: The study is being repeated. Data will then be submitted for possible publication in a scientific journal.

GROWTH AND INTERFERENCE OF PROSO MILLET IN DRYLAND CORN

R.L. Anderson, S.E. Hinkle and A.D. Halvorson
Central Plains Resources Management Research Unit

CRIS: 5407-12130-002-00D

PROBLEM:

Producers in the western part of the Central Great Plains are changing their crop rotations from winter wheat-fallow to more intensive cropping, where several crops are planted sequentially before a fallow period occurs. As producers move towards more flexibility in cropping options, one potential crop sequence would be planting dryland corn after proso millet. Wild proso millet is a prevalent weed in the northern cornbelt. Producers use intensive herbicide inputs at a high economic cost to prevent significant yield losses due to wild proso millet interference. Wild proso millet is considered to be an escaped form of cultivated proso millet, and the plant development of each biotype is very similar.

Knowledge of plant development of both proso millet and corn as affected by cultural practices may suggest possible control measures which can be incorporated in a management system, thus possibly reducing the need for extensive herbicide inputs. At present, the most successful control measures for wild proso millet have included preplant-incorporated herbicides plus postemergence directed-spray herbicides which require a substantial height differential between the millet and corn to avoid corn injury. In the Central Great Plains, however, maintaining residue on the soil surface has been advantageous for crop production. Thus, if producers wish to keep residue on the surface yet control proso millet, postemergence herbicides may be required. Knowledge of the developmental patterns of volunteer proso millet within a corn canopy may suggest possible vulnerable stages in its life cycle for cultural control and also guide effective use of postemergence-directed herbicides.

The objectives of this study are: 1) evaluate the emergence patterns and development of proso millet within a corn canopy in a no-till and tilled production system; 2) evaluate the interaction between proso millet growth stage and timing of application of nicosulfuron for proso millet control within a corn canopy; and 3) evaluate herbicides for the control of proso millet in corn.

APPROACH:

Proso millet emergence was determined for no-till and till treatments. The till treatment was disked twice two weeks before planting corn. Four m^2 sites per each tillage treatment were designated at planting, with proso millet emergence from the soil seed bank recorded weekly and the plants removed after counting. Soil temperature was measured hourly at the 1.3 cm depth with a data logger. Twelve proso millet seedlings (germinated in the greenhouse in peat pellets) were transplanted in the field in six replications every two weeks from corn planting until August 1. Development stage and plant height were recorded weekly. At maturity, the plants were harvested for biomass and seed production. Plot area was maintained weed-free by hand weeding.

Corn was planted on April 25, May 2, May 9, May 20, and May 31, at 25,200 plants/hectare. Experimental design was a randomized complete block with four replications. Plant height and development were recorded weekly on two designated plants per plot. Grain yields were recorded at harvest.

Proso millet at 4 development stages (1-2 leaves, 4-5 leaves, 1-2 tillers, and 4-5 tillers) was treated with nicosulfuron (Accent) at 35 g/ha. The experimental design was a randomized complete block with four replications. Biomass was measured 4, 7, and 10 weeks after nicosulfuron application. Grain yields were recorded at harvest. Atrazine at 1.1 kg/ha was applied in late April to weed control in the above studies.

Four herbicide treatments were evaluated for control of proso millet in corn: 1) Eradicane (EPTC) at 4.5 kg/ha + row cultivation (if needed) in late June; 2) Command (clomazone) at 0.8 kg/ha applied preemergence; 3) Command at 0.8 kg/ha applied preemergence with Bladex (cyanazine) + Prowl (pendamethalin) at 1.7 kg/ha + 1.1 kg/ha applied early postemergence (when proso millet was just emerging); 4) Command at 0.8 kg/ha + Paraquat at 0.3 kg/ha applied post-directed when corn was 40 cm in height. Atrazine at 1.1 kg/ha was applied to all treatments in late April to eliminate all other weeds. Weed-free and weed-infested controls were included for comparison. Corn was planted at 24,700 plants/ha. The experimental design was a randomized complete block design with 4 replications. Biomass measurements were taken on July 31 (at silking), and grain yields were recorded at harvest.

FINDINGS:

Proso millet began emerging by May 20 and continued until July 25. Emergence was similar between the till and no-till environments. Approximately 95% of total emergence with both environments had occurred by June 19. The total number of seedlings were 125 plants/m², approximately 10% of the previous year. Proso millet at the 1991 site was harvested earlier, thus reducing the amount of shattering and the resultant seed bank in the soil. Proso millet growth within the corn canopy was affected by time of emergence. The dry matter production of proso millet that emerged on June 1, June 15, July 1, July 15, and August 1 was 30.8, 4.4, 1.5, 0.2, and 0.1 grams/plant, respectively. A plant emerging on June 1 produced 2185 seeds, while a plant emerging 2 weeks later produced only 360 seeds. The ecological data on proso millet emergence and productivity indicates that the critical control period is between May 15 and June 21. Using post-directed applications of paraquat is very effective in controlling proso millet within corn. One critical component of this application technique is a height differential. For maximum effectiveness, corn should be at least 40 cm in height, while proso millet should be shorter than 15 cm. Corn height measurements from the date of planting study showed that if corn was planted before May 10, a sufficient height differential occurred.

Corn yield was affected by time of planting. Grain yields were 2825, 2540, 2590, 2440, and 2090 kg/ha for the April 25, May 2, May 9, May 20, and May 31 planting dates, respectively. Coupled with the height differential data, the grain yield data suggests that corn planted before May 10 allows for maximum flexibility in proso millet control while producing high grain yields.

Nicosulfuron bioactivity on proso millet was affected by growth stage. Biomass reduction by nicosulfuron was 92, 72, 68, and 45% for the 1-2 leaf, 4-5 leaf, 1-2 tiller, and 4-5 tiller development stages, respectively. Corn grain yield was reduced 12% when nicosulfuron was applied at the 1-2 leaf stage compared to the weed-free control, but 77% when application was delayed until the 4-5 leaf stage. This data indicates that nicosulfuron applied early will be effective in controlling proso millet, but that

additional weed control actions will be necessary to prevent excessive yield losses due to proso millet interference.

Eradicane + one row cultivation and Command + Paraquat (post-directed) provided excellent control of proso millet. Command + Bladex + Prowl controlled proso millet early in the growing season, but late season control declined to approximately 80%. Command alone controlled proso millet early in the growing season, but long-term control with Command will require a second weed control operation, such as row cultivation or a post herbicide application. Proso millet biomass reduction at silking showed the same trend as the visual evaluations, with Eradicane and Command + Paraquat being the most effective.

Corn yields were highest with the no-till treatments of Command + Bladex + Prowl and Command + Paraquat. The Eradicane treatment yielded less than 50% of the Command + Paraquat treatment, even though weed control levels were similar. This yield loss is attributed to the lack of residue on the soil surface (due to disking for incorporating Eradicane in early May) and 1 row cultivation operation during the growing season increasing soil water evaporation. Since the 1991 growing season was dry, this tillage effect on grain yield was magnified.

INTERPRETATION: The ecological data indicates that the critical period for proso millet to affect corn is between May 15 and June 15. Nicosulfuron controls proso millet if applied early, but its use in management systems for proso millet control will require other weed control actions, such as late season cultivation or post-directed sprays. Control of proso millet in dryland corn is achievable, but economic costs will be high.

FUTURE PLANS: This study will be conducted again next year, data will be analyzed, and submitted for possible publication. Management systems suggested by the ecological data will be examined in the future, within economic limits currently facing the producers.

PSEUDOMONAS BACTERIA AS A BIOLOGICAL CONTROL AGENT FOR DOWNY BROME IN WINTER WHEAT

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CRIS: 5407-12130-002-00D

PROBLEM:

In the United States, downy brome (Bromus tectorum L.) and related Bromus species infest an estimated 5.7 millon hectares of dryland winter wheat. At the current market value for wheat and using available herbicides, downy brome is still reducing wheat yields by an estimated 15% or 300 million dollars. In addition, these herbicides cost farmers 35 to 70 million dollars annually depending on herbicide choice and usage. Other costs include reduced harvest efficiency, increased dockage, future weed control costs, and adoption of less economic cropping systems. Also, as tillage is reduced to adopt conservation practices, the incidence of downy brome increases as does the use of chemical to control this weed.

Increased awareness of the environmental risks associated with the excessive use of chemicals to control weeds in agricultural production has stimulated investigation into the use of microorganisms as alternative control methods. Biological control can potentially reduce the dependence on chemicals and increase the cost effectiveness of pest control. Biological control using plant pathogens, usually fungi, has been effective in the control of certain weeds. Recent studies have shown the ability of deleterious rhizobacteria (Pseudomonas spp.) to suppress the growth of downy brome without injuring winter wheat.

The objective of this study is to evaluate the performance of a selected strain of Pseudomonas rhizobacteria for bioactivity on downy brome over several locations in the Western U.S. (Akron, CO, Hays KS, Pullman, WA, Pendleton, OR, and Moscow ID).

APPROACH:

Field plots were established on an Ascalon sandy loam soil. Eight treatments are being evaluated: 1) nontreated control; 2) rhizobacteria strain D7 at 10^9 bacteria/m^2; 3) diclofop at 1 kg/ha; 4) diclofop at 0.5 kg/ha; 5) rhizobacteria strain D7 at 10^9 bacteria/m^2 + diclofop at 0.5 kg/ha; 6) metribuzin at 0.3 kg/ha; 7) metribuzin at 0.15 kg/ha; and 8) rhizobacteria strain D7 at 10^9 bacteria/m^2 + metribuzin at 0.15 kg/ha. Experimental design is a randomized complete block with 4 replications. Plot size is 4m by 8m.

Soil and plant (winter wheat and downy brome) samples will be collected 0, 7, 21 days after rhizobacteria application, plus in November, February, April, and June. Samples will be sent to Pullman for rhizobacteria population measurements. Seed production and biomass of downy brome at physiological maturity of the weed will be determined in mid to late June from 2 1-m^2 sites. At winter wheat maturity, grain and biomass yield, and yield components of winter wheat will be recorded.

FINDINGS:

This study was initiated in the fall of 1991, and only microbiological data has been collected (analyzed by Ann Kennedy at Pullman, WA). The bacteria was not detected in the fall soil or plant samples. The 1991 fall was extremely dry, thus environment conditions were such that bacteria population growth did not occur. Winter precipitation may stimulate bacteria population growth, however.

The Akron site will supply data to determine if the bacteria can tolerate severe drought or high temperatures. The climatic conditions at Pullman, where the bacteria was initially discovered and isolated, are extremely different from the Great Plains. Their precipitation occurs in the fall and winter, and the fall temperatures are cooler. These conditions are more suitable for bacteria population growth.

INTERPRETATION: With the limited data set presently collected, no interpretation can be made.

FUTURE PLANS: This study will be repeated in 1992-1993.

MANAGEMENT OF PHOSPHORUS FERTILIZER FOR DRYLAND WINTER WHEAT IN REDUCED TILLAGE SYSTEMS

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CRIS: 5407-12130-002-00D

PROBLEM: Information on management of phosphorus (P) fertilizer in no-till and reduced tillage systems for winter wheat production in the Central Great Plains is limited. Banding of low rates of P near the seed on soils low in available P has been shown to be more effective than broadcast applications of P at the same rate during the first year of application. As the soil test P level increases from low to high, the yield difference between banding and broadcast applications is expected to decrease. On a long-term basis, a broadcast application of P may be equally as effective as a band application at equal rates for wheat production. Application of a one-time, high rate of P fertilizer may be one way to satisfy the P needs of crops grown with reduced tillage and no till systems for several years. This study evaluates this suggestion along with comparing the effects of P placement method on the long-term effectiveness of residual P fertilizer within reduced tillage systems. Objectives of this study are to determine: 1) the most efficient P fertilizer placement method for winter wheat production in reduced tillage systems; 2) the level of P fertilizer needed for optimum winter wheat yields with and without N fertilization; 3) residual P fertilizer effects on winter wheat grain yields in reduced tillage systems; and 4) the effects of N and P fertilization on water-use efficiency by dryland winter wheat.

APPROACH:

A split-split plot, randomized block design was used with P placement method as main plots, P fertilizer rate as subplots, and N fertilizer rate as sub-subplots with four replications. The research is located at two sites, one site about 6.2 km west of Peetz, Colorado and one site about 3.7 km southeast of Morrill, Nebraska. Specific treatments are as follows:

1) Phosphorus Fertilizer Placement Methods
a) Broadcast with no incorporation (BCNI) (Peetz site only)
b) Broadcast with a shallow disk incorporation (BCI) (15 cm depth)
c) Deep Band at about a 10 cm soil depth (DB)
d) Band directly with seed (SP) at 25% of established P rates for 4 crop years (Peetz) and 50% rate for 2 years (Morrill).

2) Phosphorus Fertilizer Rates Applied in September 1986 at Peetz
a) Peetz site -- 0, 34, 67, 101, and 134 kg P/ha
b) Morrill site -- 0, 11, 22, and 45 kg P/ha
Reapplied in fall 1990 to former BCI and SP plots at full rate

3) Nitrogen Fertilizer Rates
a) Peetz site -- 0 and 56 kg N/ha
b) Morrill site -- 0 and 56 kg N/ha

Grain yield, N and P uptake by grain, soil P, soil NO_3-N, and soil water were measured at the Peetz site.

FINDINGS:

The yield data from the Morrill site for the years 1985 to 1990 was summarized during 1991 in preparation for journal publication. Treatments at the Morrill site were changed in 1991 with reapplication of fertilizer P rates to the seed placed and deep band treatments. Downy brome was very severe at this location in 1991, consequently, yield data was highly variable with low yields. The 1991 data are not included in this report. The 1991 growing season precipitation amounted to 24.4 cm from April until July 1, 1991. However, only 3.6 cm of precipitation was received from planting on Sept. 12, 1990 until March 30, 1991. Therefore, stand establishment was poor in 1991, contributing to low yield potential. Responses of winter wheat (Cody) to residual P fertilizer were measured at this site from P applied deep band in 1984. The winter wheat showed additional responses to the P newly applied in the fall of 1990.

Total grain yields for the first 3 crops harvested at the Morrill site were significantly (0.05 probability level) increased by increasing levels of residual fertilizer P, with no significant differences between P placement methods. Total grain yields were increased from 7258 kg/ha (108 bu/a) to 8669 kg/ha (129 bu/a) with increasing rates of P application when averaged over N rates. The N x P rate interaction was significant for total grain yield (Fig. 1). The placement x P rate interaction was not significant. Thus as sufficient P is applied to optimize grain yields and eliminate P deficiency, method of placement would not appear to be critical. The data indicate that the response to residual P was similar for all placement methods. None of the other treatment interactions were significant for grain yield.

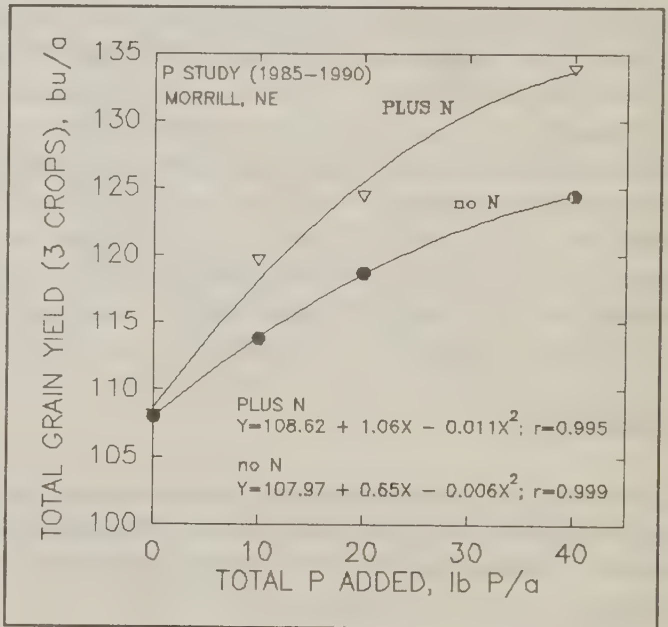

Fig. 1. Total grain yield (3 crops) as a function of N and P fertilization.

Winter wheat yields at the Peetz site were limited by poor plant growth and loss of stand over winter and poor tillering a result of water stress from planting until mid-May. During the 1991 growing season, 17.0 cm of growing season precipitation were received from April 1st until harvest, with most of the precipitation received after May 14th. Some hail in late May and June also reduced grain yield potential. Soil water measurements indicated soil water-use of 13.7 cm from the 0 to 120 cm soil depth at harvest. This resulted in an estimated total water use by the wheat crop in 1991 of about 30.7 cm.

Grain yields were significantly (0.05 probability level) increased by increasing levels of residual P or P fertilization. Grain yields were increased by N fertilization in 1991, but only by 80.6 kg/ha. Lack of a greater response to N fertilization was due to a high level of residual soil N. Grain yields for the fertilizer P treatments were 1868, 2023, 2278, 2386, and 2305 kg/ha for the 0, 34, 67, 101, and 134 kg P/ha treatments, respectively, when averaged over N rates. The Placement x P rate interaction was significant, with the yields for each P placement as a function of P rate are shown in Fig. 2. Cumulative

grain yields above the check treatment (no N or P) from three crops increased significantly with increasing levels of available P for all P placement methods. Protein, N, and P analyses of the grain, straw, and soil samples are not complete.

Phosphorus fertilization resulted in a significant increase in the number of heads per unit area at harvest. Head counts for the residual 0, 34, 67, 101, and 134 kg P/ha treatments were 4.02, 4.17, 4.37, 5.01 and 4.55 million heads/acre, respectively. Nitrogen fertilization had no significant effect on the number of heads per ha. Grain test weights were low at this site in 1991 due to plant water stress on the wheat, however, grain test weights increased with increasing levels of available P. Straw yields at harvest and total biomass yield at heading increased with increasing P level.

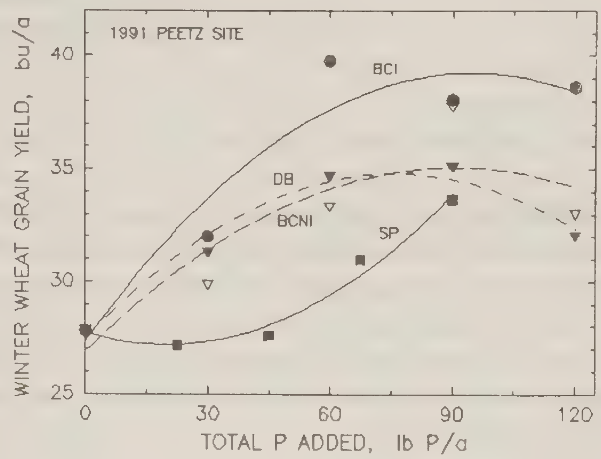

Fig. 4. Winter wheat yields at the Peetz site in 1991 as a function of P placement.

Estimated plant-available water use (evapotranspiration) was 30.7 cm in 1991 at this site. This resulted in a water-use efficiency of 60.8 kg grain/ha/cm for the check (zero P) treatment and 77.6 kg grain/ha/cm for the 101 kg P/ha treatment when averaged over N rates. Nitrogen use efficiency was slightly improved with P fertilization, as indicated by a lower quantity of residual soil nitrate-N in the soil profile at planting with increasing level of P fertilization. Nitrogen fertilization increased the level of residual N in the soil profile.

INTERPRETATION: The data from both sites show that P fertilizer is effective for more than one year. The cost of P fertilization needs to be amortized over more than one year when considering the economics of P fertilization. An economic analysis of the grain yield response from the Peetz site indicate that the 34 and 67 kg P/ha treatments were the most profitable the first year of application when applied with N for the broadcast and deep band placement methods. The estimated net returns were greater from these treatments than from any of the seed-placed P treatments during the year of application. When adding the residual P response of the second crop, the 101 and 134 kg P/ha treatments were profitable and became more profitable with the harvest of the third crop. The positive effect of residual fertilizer P on winter wheat yields is being demonstrated. However, it will be very important to continue this study as long as possible to evaluate the long-term residual P effects on grain yield and economic returns.

FUTURE PLANS: The Morrill site will be dropped for 1992 because of insufficient personnel and time to service the plots properly. The downy brome is also creating a significant problem with plot variability, causing inconsistent data. The Peetz site will be continued in 1992 as planned. Plans are to summarize the data from the Morrill site and prepare a manuscript for journal publication.

EFFECT OF NITROGEN FERTILIZATION ON WATER-USE EFFICIENCY BY CORN AND BARLEY (or W.WHEAT) GROWN IN ANNUAL CROPPING SYSTEMS

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PROBLEM: Limited water for dryland crop production in the Central Great Plains area requires that precipitation be used efficiently. Limited information is available in the Central Great Plains describing the effects of nitrogen (N) fertilization on grain yield and quality, and on water-use efficiency of barley (or winter wheat) and corn produced in a reduced tillage annual crop rotation. Basic data on soil fertility and plant water relationships for barley (or winter wheat) and corn is needed for the Central Great Plains in order to make crop management decisions that will most efficiently use limited water supplies and fertilizer inputs.

APPROACH: A dryland study site was established on a silt loam soil located on the Central Great Plains Research Station in September 1983. The fertilizer treatments were initially established in the fall of 1983. The phosphorus (P) soil test level was 26 mg/kg (ppm). The initial fertilizer treatments consisted of residual fertilizer P rates (0 and 34 kg P/ha) as main plots and fertilizer N rates (0, 22, 45, 67, 90, and 180 kg N/ha) as subplots with 4 replications in a split-plot, randomized complete block design. Due to lack of response to the residual P fertilizer rates, the plot design was changed to a simple randomized complete block design in 1987 with only N rates as treatments. The cropping history and grain yield of these treatments are given in Table 1. The plots were planted to corn (Pioneer 3732) on May 9, 1991 with a Buffalo planter at a seeding rate of 36,000 seeds/ha (14,580 seeds/acre and harvested on October 9, 1991 with a plot combine. Ammonium nitrate was broadcast applied on April 27, 1991, prior to seeding at rates of 0, 22, 45, 67, 90, and 134 kg N/ha. The 180 kg N/ha treatment from previous years was reduced to 134 kg N/ha in 1986 because of excess N in the soil profile. Soil water, nitrate-N (NO_3-N), and growing season precipitation were monitored. Grain yield and quality were determined as well as corn silage yield.

Table 1. Cropping history and grain yields.

Year	Crop	N Rate (kg/ha) 0	22	45	67	90	134
		Grain Yield, kg/ha					
1984	Barley	2753	4032	4134	4193	4322	3543
1985	Corn	3889	4453	5444	5902	5846	6209
1986	Barley	446	1167	2054	2344	2806	3097
1987	Corn (hailed out on Aug. 4, winter wheat planted Sept. 14)						
1988	Winter Wheat	2818	3258	3517	3942	3683	3448
1989	Corn	2563	3265	3332	3770	3329	4113
1990	Barley	135	442	974	1105	957	884
1991	Corn	4257	4849	5849	6416	6112	5999
Average	(8 years)	2108	2683	3162	3459	3382	3411

FINDINGS: Corn yields for the 0, 22, 45, 67, 90, and 134 kg N/ha treatments were 4257, 4849, 5849, 6416, 6112, and 5999 kg/ha or 67.8, 77.2, 93.2, 102.3, 97.4, and 95.6 bu/a at 15.5% grain moisture, respectively, for 1991. Precipitation was not limiting until August. Silage production measured on August 26, 1991 increased significantly with increasing N rate up to 67 kg N/ha. Silage yields (70% moisture) averaged 24, 30, 34, 36, 30, and 32 t/ha for the 0, 22, 45, 67, 90, and 134 kg N/ha treatments respectively. Soil-water use by corn was influenced very little by N level in the 0- to 180-cm soil profile in 1991. Soil water use from the 0- to 180-cm soil profile was estimated to be 17.1 cm. Growing season precipitation amounted to 27.8 cm for a total estimated ET of 45 cm (17.7 inches) for 1991. Thus, water-use efficiency (WUE) by dryland corn increased as N fertility level increased up to an application rate of 67 kg N/ha. WUE levels were 94.6, 107.7, 130.0, 142.6, 135.8, and 133.3 kg grain/ha/cm water for the respective N treatments. Residual soil NO_3-N levels on April 19, 1991 were 42, 56, 125, 112, 116, and 378 kg N/ha for the respective N treatments.

INTERPRETATION: The dryland corn yields at this annually cropped site were very acceptable in 1991. The corn responded very well to the soil water not used by the 1990 barley crop which was hurt by heat stress. Although rainfall was limited during the latter part of the corn growing period, the corn used soil water not used by the 1990 barley crop. This was the 8th consecutive crop produced on these plots since 1984. Thus, for an annual dryland cropping situation, the average grain yield (Table 1) with an adequate level of N are acceptable and economical, even with one year (1987) of total crop failure and one year (1990) of very low yield. The residual soil NO_3-N data indicate that efficient use of the fertilizer N has been made up to a rate of 67 kg N/ha. At the highest N rate, N fertilizer has been used less efficiently with a significant buildup of residual NO_3-N in the soil profile. These data demonstrate the potential to economically crop more frequently than every two years as is done in a crop-fallow system when adequate levels of soil water and N are available.

FUTURE PLANS: The project will be continued in 1992 with each N treatment being applied at its normal rate. Barley (Otis) will be planted no-till on the plot area in mid- to late-March 1992. Plans are to complete the summary of the results and make a detailed economic evaluation of the yield data.

CROP ROTATION AND NITROGEN FERTILIZATION FOR EFFICIENT WATER USE

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CRIS: 5407-12130-002-00D

PROBLEM: In the western portion of the Central Great Plains, the winter wheat- fallow rotation is the dominant cropping system. Diversification in crop production has been limited in this area, providing producers with few economic alternatives in years when wheat is in surplus supply or soil water levels are high. The winter wheat-fallow (WW-F) system is probably not the most efficient cropping system for utilizing precipitation. Implementation of reduced tillage and no-till cropping systems has resulted in more efficient soil storage of precipitation. This additional water savings increases the opportunities for successfully growing spring-planted crops such as proso millet, sorghum, and corn in rotation with winter wheat. However, data on the productivity of a winter wheat-corn(or sorghum)-fallow (WW-C-F or WW-S-F) rotation is limited for the western portion of the Central Great Plains. Nitrogen management information for optimum water utilization and crop yields in these cropping systems is lacking. The objectives of this study are to measure the long-term grain yields of each respective crop in WW-C-F and WW-S-F rotations and determine the effects of N fertilization on grain yields and water-use efficiency by each crop, residual NO_3-N levels, and economic returns.

APPROACH: The N treatments (0, 28, 56, 84, and 112 kg N/ha applied each crop year) are randomized in a complete block design with 4 replications on a Platner loam soil near Akron, CO. Each main N plot is split following winter wheat with half the plot planted to corn and half to sorghum. Three sets of no-till plots are used to allow each crop of the rotation to be present every year. Soil water and NO_3-N are monitored to assess use by each crop. Nitrogen was broadcast to the wheat plots September 16, 1990. Wheat (Tam 107) was planted September 20, 1990 at a rate of 2.2 million seeds/ha or 900,000 seeds/acre with a Haybuster 1000 disk-type drill (7" row spacing). Corn (Pioneer 3732) was planted May 10, 1991 (36,803 seeds/ha or 14,900 seeds/a) and sorghum (Pioneer 8790) was planted May 22, 1991 (143,260 seeds/ha or 58,000 seeds/a) on the 1990 wheat plots. Ammonium nitrate was broadcast on the corn and sorghum plots on April 26, 1991. Winter wheat was harvested July 5, corn October 7, and sorghum October 9, 1991.

FINDINGS:

Winter wheat grain yields were significantly increased by N fertilization in 1991. Grain yields averaged 2361, 3342, 3942, 4551, and 4354 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Near normal precipitation from March 1991 until July 1991 resulted in the development of a crop with excellent yield potential. Grain yields increased with increasing N rate up to 84 kg N/ha and then leveled off. As was the case in 1990, wheat yields tended to be greater where corn was the previous crop (3798 kg/ha) vs where sorghum was the previous crop (3621 kg/ha) in rotation. Residual soil NO_3-N levels on Sept. 10, 1990 were 62, 90, 85, 105, and 104 kg N/ha (0- to 120-cm soil depth) with increasing N rate prior to N fertilization and winter wheat seeding.

Growing season precipitation (April 1 to harvest) was 21.2 cm. Average soil water use (0-120 cm depth) was 10.9 cm. Water use efficiency by the winter wheat, based on gravimetrically measured soil water, was improved by N fertilization with WUE of 74, 104, 123, 142, and 136 kg grain/ha/cm water for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively.

Corn grain yields were significantly increased by N application in 1991 at this site with an average grain yield of 1430, 2760, 3023, 2942, and 3525 kg/ha at 15.5% grain moisture for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Grain yields in 1991 were lower than in 1990 due to the low soil water conditions at planting and a very low amount of growing season precipitation late in the season. Yields were highest at the highest N rate. Silage yields (70% moisture) on September 5, 1991 were 11.1, 23.2, 25.8, 23.2, and 24.5 t/ha, respectively. Soil water use averaged 14.0 cm from the 0-120 cm profile with growing season precipitation amounting to 26.8 cm for a total estimated ET of 40.8 cm.

Sorghum grain yields were significantly increased in 1991 by increasing rates of N fertilization up to 28 kg N/ha and then leveled off with increasing N rate. Grain yields on October 9, 1991 averaged 1951, 3012, 2600, 2386, and 2634 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments, respectively. Average soil water use by the sorghum was estimated to be 14.8 cm from the 0-120 cm soil depth. Growing season precipitation was 26.8 cm. Estimated ET for the sorghum crop was 41.6 cm. Laboratory analyses for soil NO_3-N, and grain protein are in progress.

INTERPRETATION: Crop yields were averaged with previous years, resulting in average winter wheat yields (7 yr) of 2289, 3048, 3395, <u>3605</u>, and 3539 kg/ha; corn yields (6 yr) of 1732, 2623, 3011, 2920, and <u>3155</u> kg/ha; and sorghum yields (6 yr) of 1574, 2266, <u>2463</u>, 2352, and 2187 kg/ha for the 0, 28, 56, 84, and 112 kg N/ha treatments. Average grain and sorghum yields include the 1987 yields severely damaged by hail on August 4th (>60% loss). The winter wheat, corn, and sorghum yields at this site on this shallow soil (<120 cm to gravel) indicate the potential for more intensive crop rotations for the dryland areas of the Central Great Plains. Fertilization with N will be essential to maintain economic yields. Water use efficiency by dryland crops (winter wheat, corn, and sorghum) can be significantly increased by the application of N fertilizer. Application of 84 kg N/ha to each crop has resulted in optimum wheat yields, while 56 kg N/ha was needed for sorghum and 112 kg N/ha for corn when averaged over years.

FUTURE PLANS:: The study will be continued in 1992 as planned with the same N rates and rotation of crops. The plots will be soil sampled to assess changes in soil chemical and physical properties. The cooperative N^{15} work with Drs. Follett and Porter will continue in 1992 with the plots possibly planted to sorghum. Plans are to continue data summarization and preparation of data for publication and economic analysis.

MANAGEMENT OF NITROGEN FERTILIZER WITH ANNUAL CROPPING IN REDUCED TILLAGE SYSTEMS

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PROBLEM: Nitrogen fertilizer management information for crops grown in annual dryland cropping systems in the western Central Great Plains is limited. Annual cropping systems generally require more fertilizer N than a crop-fallow system to obtain optimum grain yields. Use of a flexible cropping system, where soil water at planting is evaluated, will reduce the potential for an uneconomical return and make better use of limited water supplies in rainfed cropping systems. Broadcast N applications to reduced- and no-till cropping systems without incorporation may result in N loss through volatilization and microbial tie-up. Banding N fertilizer below the soil surface may result in less microbial tie-up and more efficient use by crops. Prior to 1990, the study objective was to evaluate the effects N placement method (broadcast vs band) and N rate had on dryland crop yields within an annual cropping system using reduced-tillage methods where winter wheat and spring barley were grown in an annual cropping rotation. Over the long-term, the economics of N rate and annual crop rotation versus a crop-fallow rotation will be evaluated. In 1990, the crop rotation was altered to a flexible cropping system with sunflower being grown in 1990 and proso millet in 1991 with no additional N applied to the previous N treatments in 1991.

APPROACH: A randomized, complete block design with factorial combinations of five N fertilizer rates (0, 34, 67, 101, and 134 kg N/ha) and two N placement methods (band and broadcast) with 4 replications was used. However, in 1991, no additional nitrogen fertilizer was applied to any of the previous N treatments because of high levels of residual soil N from N application in previous years. An adjacent winter wheat-fallow area was maintained for comparison with the annual crop yields. Proso millet (Sunup) was planted on the annual crop plots on June 10 with a Haybuster 1000 disk drill (11.2 kg seed/ha), swathed on September 9, and combined for yield determination on September 10, 1991. The study is located on a silt loam soil at the Central Great Plains Research Station. Grain yield, nutrient uptake, soil water, and residual soil NO_3-N were measured. Sunflowers were grown on these same plots in 1990, winter wheat in 1989, spring barley in 1988, winter wheat in 1987, spring barley in 1986, and winter wheat in 1985 and 1984. The 1986 barley crop was removed from the plot area on June 6th because of a severe infestation of downy brome. Very little downy brome was present in the 1989 winter wheat crop.

FINDINGS:

Soil water in the annual crop plots was minimal at the time the proso millet was planted and was 6.7 cm less than in the fallow plots (Table 1). Only the top 30 cm of soil had been recharged to near field capacity at the time of May 19, 1991 soil sampling. Below normal precipitation from planting to harvest further reduced yield potential, with a growing season precipitation level of 20.6 cm. Proso millet grain yields were not increased by increasing levels of available N in 1991. Annual cropping proso millet yields averaged 900, 984, 1012, 1004, and 991 kg/ha for the broadcast plots which received no additional N in 1991 and 1205, 1026, 524, 880, and 1070 kg/ha for the band plots which received no additional N in 1990 or 1991 for the 0, 34, 67, 101, and 134 kg N/ha treatments, respectively. The average proso millet yield was 981 kg/ha when averaged over all N treatments in 1991. It would appear that there was

insufficient available soil water to sustain a high yield potential on the annual crop plots in 1991. Estimated evapotranspiration (ET) by proso millet within the annual cropping system was 21.6 cm (20.6 cm precipitation plus 1.0 cm soil water use, 0-180 cm depth). Average water use efficiency (WUE) was 45.4 kg/ha/cm in 1991.

Residual soil NO_3-N levels in the 0-180 cm soil profile after the 1990 sunflower harvest were 54, 131, 185, 379, and 623 kg N/ha for the residual broadcast treatments and 39, 31, 152, 209, and 515 kg N/ha for the residual band N treatments for the 0, 34, 67, 101, and 134 kg/ha N rates, respectively. With the low yields in 1991, these residual NO_3-N levels are expected to increase with another application of N for the 1992 crop. Laboratory analyses are in progress to determine 1991 soil N, grain protein, and nutrient uptake levels.

Table 1. Soil water content in Spring and after proso millet harvest (September 13, 1991) for the annual cropping and crop-fallow plots.

Soil Depth	Annual Cropping System 5-19-91	Annual Cropping System 9-13-91	Fallow 4-24-91
cm	cm/depth		
0-15	3.10	1.85	3.68
15-30	3.29	2.38	4.38
30-60	5.76	5.90	9.59
60-90	4.73	4.63	7.92
90-120	3.72	4.11	6.30
120-180	8.17	8.92	10.45

INTERPRETATION: Proso millet yields were limited severely by lack of soil water and low growing season precipitation levels in 1991. A decision to fallow these plots in 1991 would have been a better agronomic decision. Response to N fertilization will be limited in years of low water supply. The 67 kg N/ha treatment has been sufficient to optimize grain yields over the long-term. This also explains why residual soil NO_3-N increased significantly for the N rates greater than 67 kg N/ha.

FUTURE PLANS: The study will be continued with some planned changes for 1992. If adequate levels of stored soil water are available in early May 1992, corn will be planted. If soil water has not been adequately recharged by over winter precipitation in the 0-90 cm soil depth, the plots will be fallowed and planted to winter wheat in September 1992. Only the broadcast N plots will continue to receive additional N in the future. Recovery of the residual N from the band plots will be studied. Data collected to date will be summarized over years and prepared for possible economic evaluation.

EFFECT OF TILLAGE SYSTEM AND CROP ROTATION ON WINTER WHEAT YIELDS

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PROBLEM: The winter wheat-fallow (WW-F) rotation is the accepted conventional crop management practice for most of the western portion of the Central Great Plains. Weeds are generally controlled during the fallow period before winter wheat planting with 4 to 6 tillage operations. Weed control with herbicides rather than mechanical tillage has made possible the adoption of reduced and no-till systems for winter wheat production. The reduced-till systems improve soil water storage efficiency during the fallow period, and often result in increased wheat yields. However, costs of herbicides for weed control during the fallow period can often result in lower economic returns than when mechanical tillage is used. Wheat yields in a winter wheat-corn-fallow (WW-C-F) rotation may be higher than wheat yields in a WW-F rotation, thus making reduced and no-till systems more economical. This study compares the effects of tillage system in a WW-F rotation with wheat yields produced in a no-till WW-C-F rotation. The study continues 3 tillage treatments from a long-term WW-F study started in 1975 and modifies 5 reduced-till treatments to include 3 no-till treatments with a WW-C-F rotation, and one no-till treatment with continuous corn (CC). One treatment will be converted to a black fallow (no crop residue) using a plow or disk to bury the crop residue with a WW-F rotation. Specific objectives are to determine: 1) effects of tillage system on soil chemical, physical, and biological factors and productivity; 2) effects of crop rotation on soil chemical, physical, and biological factors as well as productivity; 3) economics of various tillage systems for WW-F; and 4) differences in wheat yields obtained from a WW-F rotation and those produced with a WW-C-F rotation.

APPROACH:

This dryland study is located on a Weld silt loam at the Central Great Plains Research Station, Akron, CO. The modifications to the existing two sets of identical plots were made on April 15, 1989. Anhydrous ammonia fertilizer, 56 kg N/ha, was applied using a Yetter rolling coulter several weeks before planting winter wheat (Tam 200) on September 20, 1990 with a Haybuster 1000 series disk drill (7 inch row spacing). Winter wheat was seeded at a rate of 2,124,200 seeds/ha on the north plots and 2,247,700 seeds/ha on the south plots. The south wheat plots were planted with a Haybuster 8000 series hoe drill. Corn (Pioneer 3732) was planted on the appropriate treatments on May 21, 1991 at a rate of 37,000 seeds/ha with a JD Maxemerge planter. Corn was seeded on plots that had been in wheat in 1990. Anhydrous ammonia, 84 kg N/ha, was applied a couple of weeks before planting the corn. Specific treatments are as follows:

1) No till (NT) - Contact and residual herbicides for weed control
2) Bare Fallow (BF) - Sweep tillage in fall, plow in spring then sweep tillage
3) Stubble Mulch Fallow (SM)- Sweep, rod weeder (no plow or disk)
4) Reduced Tillage (RT)- Residual Herbicide after harvest, then spring till
5) Winter wheat-Corn-Fallow (WW-C-F) using a no-till system
6) Corn-Fallow-Winter Wheat (C-F-WW) using a no-till system
7) Fallow-Winter Wheat-Corn (F-WW-C) using a no-till system
8) Continuous Corn (CC) using a no-till system

Treatments 1-4 will be maintained in a WW-F rotation, with the fallow treatments described above. Primary data to be collected from the plots include: total soil N in 0-5, 5-10, 10-20 cm depth (Gary Peterson), soil water - preplant and after harvest (rooting depth), soil NO_3-N in 0-180 cm, grain and straw yield, crop residue - postharvest and preplant (Gary Peterson), grain test weight, N content, number of tillage and herbicide operations performed and costs. Other factors to be measured as time and resources permit will be: microbial biomass, N mineralization, aggregate stability, bulk density, soil texture, and infiltration as affected by tillage system.

FINDINGS:

The 1991 winter wheat grain yield data for the NT, RT, SM, BF, and WW-C-F plots were 3869, 4042, 3807, 3532, and 4190 kg/ha, respectively. Soil water use from the 0-180 cm profile for these same plots was 13.7, 16.4, 14.8, 11.6, and 16.0 cm, respectively. Growing season precipitation (April 1 to harvest) was 21.2 cm for a total estimated ET of 34.4, 37.6, 36.0, 32.8, and 37.2 cm, respectively. Average water use efficiencies were 65.5, 57.7, 69.1, 62.1, and 58.5 kg/ha/cm for the NT, RT, SM, BF, and WW-C-F treatments, respectively. Average soil surface residue levels on September 10, 1990 before wheat planting were 714, 627, 627, 106, and 1759 kg/ha for the NT, RT, SM, BF, and WW-C-F plots, respectively.

Grain yields of the corn grown on those plots that were in winter wheat in 1990 (WW-C-F rotation) averaged 3028 kg/ha (48.2 bu/a) and those that were in corn in 1990 (CC rotation) averaged 503 kg/ha (8.0 bu/a). Most of the corn plants in the continuous corn plots had no ears in 1991 because of no soil water storage from harvest of the 1990 corn crop and planting of the 1991 corn crop. Corn silage yields (70% moisture) were 18.0 and 25.3 t/ha for the continuous corn and C-F-WW plots, respectively. Soil water use by corn averaged 10.2 cm for the continuous corn plots and 9.8 cm for the C-F-WW plots from the 0- to 180-cm soil depth. Growing season precipitation (April 25 to Oct 10, 1991) was 19.1 cm for a total estimated ET of 29.3 cm for the CC rotation plots and 28.9 cm for the corn grown on 1990 wheat stubble for the C-F-WW rotation plots. Water use efficiencies by corn were 17.2 kg/ha/cm for the continuous corn rotation plots and 104.8 kg/ha/cm for the corn grown on 1990 wheat stubble in the C-F-WW rotation plots.

INTERPRETATION: The winter wheat yields reflected somewhat the same relative yield order as in the past, WWCF > RT > NT > SM > BF. The corn yields reflect the importance of soil water in obtaining an acceptable yield level following a previous crop in a crop rotation system. Several more years of data will be needed before the new treatment effects can be evaluated.

FUTURE PLANS: The study will be continued as revised in the spring of 1989. The 1992 winter wheat crop should allow comparisons to be made between the WW-F and WW-C-F rotations. Soil organic matter, total N and total C levels will be determined on the detailed soil samples collected in the spring of 1989.

EVALUATION OF MANAGEMENT PRACTICES FOR CONVERTING CONSERVATION RESERVE PROGRAM (CRP) LAND BACK TO CROPLAND

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PROBLEM: In response to the Conservation Reserve Program (CRP), which was initiated as part of the 1985 Food Security Act, 30.6 million acres of highly erodible cropland has been seeded to grass. At the end of the eighth sign-up period (June 14, 1989), the Great Plains had the five states with the largest number of acres committed to CRP (Texas, 3.7 million; North Dakota, 2.6 million; Kansas, 2.5 million; Montana, 2.5 million; and Colorado, 1.8 million acres). At the end of 10 years, the land may be converted back to cropland or left in grass. Answers are needed to these questions: 1) Can the land be brought back into crop production in such a manner as to continue the wind erosion protection that the grass provided?; 2) What sort of fertility program will be needed to maintain any buildup in soil organic matter that may have occurred?; 3) Will tillage be needed to convert grassland back to cropland and if so, what initial and long-term tillage practices should be used?; 4) Can herbicides be used to initially kill the existing grass and control the grass without injury to the new crops produced with a no-till system?; 5) Can more productive and profitable cropping systems that control soil erosion be used when converting the grassland back to cropland than the previously practiced wheat-fallow system?; 6) Can productivity of the grassland be increased by N fertilization or introduction of legumes/other grass species to encourage farmers to keep the land in grass? With these thoughts in mind, research was initiated in the spring of 1990 at the Central Great Plains Research Station to provide answers to some of these questions. The study objectives are to: 1) determine if CRP land can be converted to cropland using strictly no-till practices; 2) determine what effect tillage method used in converting CRP land to cropland has on crop yield, surface crop residue, water infiltration, soil erodibility, and profitability; 3) evaluate initial weed problems (1st two years) and the need for herbicides/tillage for weed control purposes; and 4) determine if grass production on CRP land can be increased by N fertilization and/or introduction of legumes.

APPROACH:

The study is located on a Weld silt loam soil on the Central Great Plains Research Station. The study area was in crop approximately 15 years ago and then was planted back to grass. Grass composition of the site was determined before implementing treatments. A split-plot, randomized complete block design with 3 replications will be used with tillage treatment as main plots and N rate as subplots. The treatments include:

1) Tillage: a) No-till (chemical control of grass before planting); b) reduced tillage (one application of glyphosate plus 2,4-D, sweep plow once or twice); and c) complete tillage (initial tillage with sweep plow, disk if needed; then conventional tillage, 4-6 operations with sweep plow and 1 operation with rod weeder).
2) Fertility: 0, 45, 90 kg N/ha (applied at or prior to planting)
3) Crop Rotation:
   Winter Wheat-Corn-Fallow on cropped ground.
   Grass with or without introduced alfalfa (established only 1st year).

The grass was sprayed with glyphosate and dicamba on the no-till and reduced-till plots on May 7, 1990, soon after the grass greened up in the spring and was actively growing. The plots were either tilled or chemically fallowed or both until winter wheat planting in September 1990. A new set of tillage plots will be established each year for 3 years. Crop yields will be monitored on each plot for two crops in a wheat-corn-fallow rotation. Alfalfa was planted in the grass-alfalfa plots on May 5, 1990 at a rate of 2.2 kg seed/ha with a JD disk drill that had a grass-legume box attachment. Poor stands of alfalfa were established. Winter wheat (Tam 107) was planted with a Haybuster 1000 series disk drill on September 2, 1990 with 22 kg P/ha placed with the seed. The seeding rate was 2,016,000 seeds/ha (900,000 seeds/acre). The wheat plots were harvested on July 5, 1991. The grass and grass-alfalfa plots were harvested on June 14, 1991 by cutting 0.61 x 12.2 m sections from the center of each plot.
Crop yields from this CRP study will be compared to yields of crop produced on a nearby Weld silt loam soil that has been cropped for more than 50 years (Long-term Tillage Study). Data to be collected include: 1) crop and forage yields; 2) soil water, 0-180 cm depth; 3) soil nitrate-N, 0-180 cm depth; 4) crop residue level, postharvest and preplant; 5) infiltration rate; 6) precipitation; and 7) weed problems.

FINDINGS:

Average grass-legume composition before treatments application was 80.1% crested wheatgrass, 13.6% blue grama, 1.7% sand dropseed, and 4.6% alfalfa. The no-till (NT) and reduced-till (RT) plots were sprayed the first time with glyphosate on May 7, 1990 and again on May 22nd because of an error in glyphosate concentration at the first spraying. The NT plots were sprayed again on July 11 with glyphosate and on August 16 and September 12 with paraquat. The RT plots were sweep plowed with a Haybuster undercutter on July 16, August 16 and 30, 1990. The conventional-till plots (CT) were sweep plowed with a Haybuster undercutter on May 22, disked twice on July 16, and undercut again on August 30, 1990. On September 11, 1990, surface residue measurements indicated that the NT, RT, CT, grass, and grass plus legume plots had an average of 75, 45, 26, 83, and 87% cover, respectively. The dry weight of the residue on the NT, RT, and CT plots was 1458, 1138, and 358 kg/ha, respectively. Increases in soil water from May 11 until September 17, 1990 were 4.7, 7.6, and 8.0 cm in the 180-cm soil profile for the NT, RT, and CT treatments respectively. Difficulty in killing the grass with herbicide in the NT plots may explain why this treatment accumulated less stored soil water than the RT and CT plots. This more than likely resulted in a lower winter wheat yield potential for the NT plots. Soil water in the grass plots increased by 1.6 cm during this same time period.

The following are results from the plots established in 1990 that were seeded to winter wheat in September 1990. Winter wheat yields averaged 3606, 3440, and 2544 kg/ha for the CT, RT, and NT treatments, respectively, when averaged over N rates. Application of 45 kg N/ha was sufficient in 1991 to optimize winter wheat yields. The reason the NT yields were significantly lower than the other tillage treatments can be explained by the fact that the NT plots had less stored soil water than the CT or RT plots at planting. Average response to N was 2789, 3420, and 3376 kg/ha for the 0, 45, and 90 kg N/ha rates, respectively. Soil water use by the winter wheat was 12.6, 10.5, and 7.1 cm in the 0- to 180-cm soil depth in 1991 for the CT, RT, and NT treatments respectively. Precipitation from April 1 to July 15, 1991 was 21.2 cm for an estimated total ET of 33.8, 31.7, and 28.3 cm. Thus the lower soil water for the NT plots at planting and little over-winter precipitation contributed to the lower yields of the NT plots.

Grass yields were 2247, 2732, and 2970 for the 0, 45, and 90 kg N/ha treatments, respectively. Alfalfa plus grass yields were 1981, 2600, and 2594 kg/ha for each of the respective N rates. Poor stands of alfalfa were establish in 1991, therefore, the alfalfa will be reseeded in 1992 on the 1991 plots as well as a new set of plots.

INTERPRETATION: The CT plots had the highest yields in 1991 because of the greater amount of stored soil water at planting. The first year data indicate that soil water storage was less in the NT plots because we had trouble killing the grass during the 1990 fallow period with herbicides. The RT treatment had more residue at planting than the CT plots, therefore, would be more desirable. Changes in the way the herbicides were applied to the grass for the 1992 plots may change the picture for the NT and RT treatments as well as the timing of the tillage operations in the RT plots.

FUTURE PLANS: Plans are to initiate the final 3rd set of NT, RT, and CT plots in 1992 for a 1993 wheat crop. Corn will be planted in 1992 where wheat was harvested in 1991. The study will continue as outlined. Consideration will be given to an earlier initial tillage date in 1992 and to making the first operation in the fall for the RT treatment a tillage operation (undercut with blade) followed by herbicide application in the spring to enhance a more rapid kill of the grass. This may result in a higher level of soil water storage.

EVALUATION OF ALTERNATIVE CROP ROTATIONS TO WINTER WHEAT-FALLOW

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PROBLEM: Economic strength, social stability, and a sustainable, environmentally acceptable agriculture throughout the Central Great Plains region depends on maximizing crop water use efficiency. Present cultural practices, using the winter wheat-fallow (WW-F) system, have resulted in extensive erosion by wind and water and a dependence on government subsidies. Saline seep development indicates inefficient water use in many areas of the Central Great Plains. Conservation tillage practices to control soil erosion further compound water problems because of enhanced infiltration of water into the subsoil. When this water is not used by crops, movement of soluble salts and agricultural chemicals into the ground water is accelerated or unproductive saline seep areas develop. National concerns for promoting an economically sustainable agriculture, which is environmentally sound, gives impetus to the need to develop dryland cropping systems that promote more efficient use of soil and water. New cropping systems that maximize the use of water can increase profits for Colorado, Nebraska, Kansas, and Wyoming farmers and ranchers. Cropping systems that include spring crops in the rotation will also provide extra benefits by helping control winter annual grassy weeds, such as jointed goatgrass, downy brome, and volunteer rye. The objectives of this proposed research are to: 1) evaluate crop rotations for more efficient water use and economic sustainability; 2) develop cropping systems that provide needed soil erosion control from wind and water; 3) reduce chemical inputs for weed, disease, and insect control in cropping systems through crop rotation; and 4) protect the soil resource base, environmental quality, and ground water quality with cropping systems that utilize water efficiently and control soil erosion.

APPROACH: The crop rotations were initiated in the spring of 1990 on a Weld silt loam soil at the Central Great Plains Research Station using a randomized, complete block design with 3 replications. Sufficient N was applied to each crop to optimize yield potential. A one time application of phosphorus, at a rate of 56 kg P/ha, was applied to eliminate P as a deficient nutrient on all plots. Three tillage treatments are being compared for the winter wheat-fallow rotation: 1) complete-till (CT); 2) reduced-till (RT) and 3) no-till (NT). Because reduced- or no-till conditions are needed to efficiently store enough soil water between crops to make the more intensive rotations (other than WW-F) successful, a no-till or reduced-till system is being used with all other crop rotations. Tillage in these systems will be for the purpose of herbicide incorporation or to achieve occasional weed control. Crop rotations are shown in Table 1 with the 1991 yield results.

FINDINGS: All crops to be included in the study were planted as scheduled for harvest in 1991. Average 1991 grain/forage yields are shown in Table 1. Safflower stands were only fair in 1991, thus contributing to low yields. The sunflower plots were seeded 3 times, only to be destroyed by gophers and birds before the sunflower could germinate and establish. After the 3rd failure at establishing the sunflower plots, forage millet was planted on these plots in 1991. This is very unfortunate since 1990 sunflowers in rotation with corn had a very significant impact on corn yields in 1991. Austrian Winter Pea stands were excellent in 1991 but grain yields (1116 kg/ha) were reduced by heat and water stress in late June. Soybean looked good most of the summer, but suffered from water stress late in the growing season. Corn grain yields varied greatly, depending on previous crop grown in the rotation and

the amount of soil water available at planting. The alfalfa and grass-legume treatments were harvested in 1991. These are only one year results and do not reflect the rotational effects at this point. Variability between reps was high in 1991 because of the influence of previous cropping histories on the land that the study occupies. This variability should diminish in 1992 as soil water levels become more reflective of the previous crop and rotation.

Table 1. Forage and grain yields for the various rotations and tillage treatments.

Rotation	Tillage	Forage kg/ha	Grain kg/ha	Grain bu/a
MONO-CULTURE				
1) M	NT	4975	1956	34.9
2) ALF	NT	2798	----	----
3) G-ALF	NT	2791	----	----
2-YEAR ROTATIONS				
4) W-F	CT	7269	3123	46.5
W-F	RT	8702	3733	55.6
W-F	NT	7800	3042	45.3
5) W-M	NT	6115	2533	37.7
M-W	NT	5289	1374	24.5
6) W-SC	NT	4273	1732	25.8
SC-W	NT	18.77(t/ha)	----	----
7) W-AWP	RT	6475	2391	35.6
AWP-W	RT	2978	1116	16.6
8) FM-C	NT	5016	----	----
C-FM	NT	4003	976	15.5
9) M-SUN	RT	3099	960	17.1
SUN-M (FM 1991)	RT	2998	----	----
10) C-SUN	RT	3092	366	5.8
SUN-C (FM 1991)	RT	2939	----	----
11) C-M	NT	5105	2111	33.7
M-C	NT	4252	1612	28.8
3-YEAR ROTATIONS				
12) W-C-F	NT	8606	3496	52.0
C-F-W	NT	6455	1435	22.9
W-C-F	RT	9549	3767	56.1
C-F-W	RT	4389	1752	27.6
13) W-C-M	NT	5131	2466	36.7
C-M-W	NT	6741	2098	33.4
M-W-C	NT	4921	1699	30.3
14) W-SAF-M	RT	4633	2199	32.7
SAF-M-W	RT	2660	738	14.6
M-W-SAF	RT	4476	1465	26.2
15) W-M-F	RT	6806	2981	44.4
M-F-W	RT	5975	2096	37.4
16) W-SOY-O	RT	7890	2288	34.0
SOY-O-W	RT	3048	586	8.7
O-W-SOY	RT	2134	939	26.2

Rotation	Tillage	Forage	Grain	Grain
4-YEAR ROTATIONS				
17) W-C-M-F	NT	8368	3278	48.8
C-M-F-W	NT	6100	2297	36.6
M-F-W-C	NT	3963	1702	30.4
4-YEAR ROTATIONS CONTINUED			kg/ha	bu/a
18) W-M-C-F	RT	7088	3310	49.3
M-C-F-W	RT	5047	1427	25.5
C-F-W-M	RT	5445	2322	37.0
W-M-C-F	NT	7790	3273	48.7
M-C-F-W	NT	6713	2869	51.2
C-F-W-M	NT	5691	1923	30.7
19) W-C-SAF-F	RT	8665	3308	49.2
C-SAF-F-W	RT	5095	2054	32.8
SAF-F-W-C	RT	2552	363	7.2
FLEXCROPPING				
20) FLEX(SORG.)	RT	----	1297	20.7
FLEX(SORG.)	NT	----	1994	31.8

Symbols: ALF=alfalfa; C=corn; F=fallow; FLEX=flexible cropping; FM=forage millet; G=grass; M=proso millet; O=oats; Pea=Austrian Winter Pea; SAF=safflower; SC=silage corn; SOY=soybean; SUN=sunflower; W=winter wheat

INTERPRETATION: This is the first year of yield data for all plots, therefore, no conclusions will be drawn on one year of data. Variability was high in 1991 because of the influence of previous cropping systems on this land before initiation of this study in 1990. Replication variability is expected to be much less in 1992. One obvious result in 1991 was that corn following sunflowers in rotation resulted in near zero corn yields because of very low soil water levels at planting.

FUTURE PLANS: All plots will be planted as planned for the 1992 crop year. An Austrian winter pea (Tinga flat pea) plus oats will be seeded as a forage combination on the one remaining blank plots. Extra plots were added to the north end of the experiment to allow for future expansion if necessary.

CROP ROTATION AND TILLAGE EFFECTS ON WATER USE, WATER STRESS, AND YIELD OF ALTERNATIVE CROP ROTATIONS FOR THE CENTRAL GREAT PLAINS

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PROBLEM: To make agricultural productivity economically sustainable and environmentally benign requires use of good agronomic practices. Crop rotation is a good agronomic practice because of the opportunities to make efficient use of precipitation, rotate herbicides and insecticides, reduce use of pesticides, and diversify farm production. Increased use of conservation tillage practices has made more soil moisture available for crop production in the central Great Plains, thereby providing greater opportunities for more intensive crop production as compared with conventional wheat-fallow. Precipitation timing and amounts exhibit wide variation from year to year in this area, producing variation in timing and severity of water stress. Some Global Circulation Models predict increased variability of precipitation, as well as a warmer, drier climate in some regions of the United States. The central Great Plains offers an ideal location in which to study cropping systems which can ameliorate high temperature and limited precipitation stresses. Growing public concern with agricultural contamination of the environment calls for research into production systems which use fewer chemicals and which intercept those chemicals before they reach groundwater supplies. Information is needed regarding water use patterns, rooting depth, evapotranspiration/yield relationships, and water stress effects of crops grown in proposed alternative rotations for the central Great Plains. The specific objectives of this experiment are to quantify the following quantities for alternative crop rotations and compare them with those obtained from conventional wheat-fallow:

1. Water use amounts during vegetative, reproductive and grain-filling growth stages
2. Depth of water extraction
3. Water stress during vegetative, reproductive and grain-filling growth stages
4. Water use-yield relationships
5. Long-term water balance and precipitation storage and use efficiencies
6. Long-term water movement in the soil that could move pesticides and fertilizers into ground water

APPROACH:

Twenty crop rotations were established at the Central Great Plains Research Station in the spring of 1990. Of these, seven were selected for intensive measurements of water use and water stress effects on yield. The seven rotations were selected over others because of the hypothesized differences in rooting depth, water extraction ability, water requirement, and sensitivity to water stress. The seven rotations are:

1. Wheat-Fallow (conventional till)
2. Wheat-Fallow (no-till)
3. Wheat-Corn-Fallow (no-till)
4. Wheat-Safflower-Fallow (reduced-till)
5. Wheat-Corn-Millet (no-till)
6. Corn-Sunflower (reduced-till)
7. FLEX cropping

FLEX plots were planted to grain sorghum in 1991 (following a corn crop on 1990). Each of the rotations is replicated 3 times, and every phase of each rotation appears every year. Plot size is 9.1 m by 30.5 m. Measurements of soil water content are taken at two locations in each plot at weekly intervals using a neutron probe at depths of 0.15, 0.45, 0.75, 1.05, 1.35, and 1.65 m. Soil water content in the 0-0.30 m layer is also determined by Time Domain Relectometry. Precipitation is measured adjacent to the plot area episodically. From these measurements, evapotranspiration is calculated by the water balance method, and rooting depth is estimated from observations of soil water depletion.

An infrared thermometer is used to measure canopy or leaf temperatures, and a psychrometer is used to measure wet and dry bulb air temperatures as often as possible during the growing season when clear skies prevail. .These measurements are used to calculate the Crop Water Stress Index (CWSI) to quantify water stress. Net photosynthesis rate, transpiration rate, and stomatal conductance are measured weekly at midday on six leaves of each plot in the second replication using a portable photosynthesis system. During 1991 measurements were only made on corn, sorghum and millet plots due to equipment, time, and personnel constraints.

Leaf area index, crop height, and plant growth stage are measured weekly to quantify water stress effects on plant growth and development. Final grain yields are taken to quantify water stress effects on plant productivity.

FINDINGS:

This was a good year for determining weak areas in our methodology for working with such a large number of measurements. We found that, with the existing personnel, we are at our limit with the seven current rotations in the number of plots that we can reasonably get measured on a consistent, routine basis throughout the growing season.

The leaf chamber measurements appear to be well correlated with CWSI so that the more frequent CWSI measurements can be used to infer photosynthesis rate, transpiration rate, and stomatal conductance. Table 1 shows a summary of the data collected in 1991 in a greatly reduced form, but trends are still evident. Wheat grown on fallow had the highest starting soil water contents, and the no-till fallow had the most available soil water in the spring. The lowest starting soil water contents were found for corn planted on sunflower stubble, wheat planted on millet stubble, and millet planted on safflower stubble. These differences in starting spring soil water contents were reflected in the relative levels of water stress throughout the growing season, photosynthesis and transpirations rates, leaf area development, seasonal water use, and final grain yield. Rooting depths were severely restricted for 1991 crops grown on millet or sunflower stubble due to very dry soil layers below about 75 cm. Summer fallow precipitation storage efficiencies were not significantly different among the three fallow treatments, and averaged about 15%.

A major setback occurred this year with the failure to establish a sunflower crop due to rodents eating the seed shortly after planting. This will not allow us to test the viability of corn following sunflower (a failure during 1991) under differing environmental conditions during 1992.

INTERPRETATION:

Some caution must be used in interpreting the data from 1991 since none of the 3-year rotations have existed long enough to go through a complete cycle, and because the rotations in Rep 3 are not fully correct due to alternative plantings to remove a herbicide carryover problem, and missing plant stands due to the same carryover problem.

October 1990 through February 1991 precipitation was 86% of normal. March through June precipitation was 101% of normal and May through September precipitation was 92% of normal, with March, May, and July having above normal precipitation. So the 1991 data give a good indication of the importance of starting soil water content in the spring, as determined by previous crop in the rotation, on every aspect of water stress, plant development, and yield during a normal precipitation year following a slightly below normal winter precipitation accumulation. Above normal precipitation during the winter and spring will be required to recharge soil profiles for the 1992 rotations of corn-millet-wheat, safflower-millet-wheat, and sunflower-corn.

After a few more cycles of these rotations when soil surface residues are more fully established, and after going through some above normal and below normal precipitation conditions, we should be better able to evaluate the successful rotations to be used in the central Great Plains, and understand why they are successful in terms of soil water storage and seasonal water stress effects.

FUTURE PLANS: Next year we plan to continue all of the measurements made in 1991, but to add photosynthesis chamber and pressure bomb measurements (leaf water potential) for all of the plots. Also, access tubes will be installed in the sunflower and safflower plots to get water use data on these crops.

Table 1. Summary of yield, cumulative evaportranspiration (CET), rooting depth, starting spring soil water content, maximum leaf area index (LAI), average seasonal Crop Water Stress Index (CWSI), photosynthesis rate (Ps), stomatal conductance (Cs), and transpiration rate (Tr) for selected alternative crop rotations, 1991.

Crop	Rotation	Yield (kg/ha)	CET (cm)	Rooting Depth (cm)	Starting Soil Water (cm/180cm)	Maximum LAI	Average CWSI	Leaf Ps[§] Rate μmol $m^{-2}s^{-1}$	Leaf Cs[§] mol $m^{-2}s^{-1}$	Leaf Tr[§] Rate mg $m^{-2}s^{-1}$
Wheat*	WF (NT)	3521	32.9	165	11.7	3.38	.37	----	----	----
Wheat*	WF (CT)	3118	27.7	120	8.8	2.70	.35	----	----	----
Wheat*	WCF (NT)‡	3481	31.0	150	10.4	3.50	.29	----	----	----
Wheat†	WCM (NT)	2466	22.0	65	6.2	2.09	.46	----	----	----
Wheat†	WSAFM (RT)	2197	22.0	85	6.8	2.22	.44	----	----	----
Corn*	CFW (NT)	2015	24.1	165	11.9	2.34	.65	14.62	.1440	98.38
Corn*	CMW (NT)	1385	20.5	150	9.4	1.74	.72	8.29	.0662	54.33
Corn*	CSUN (RT)	0	14.0	45	4.9	1.08	.99	4.65	.0417	39.86
Sorghum*	FLEX (NT)	1261	24.0	165	10.8	1.72	.71	22.26	.2040	149.43
Millet†	MWC (NT)	1874	18.2	105	8.6	2.34	.48	23.53	.2227	191.98
Millet†	MWSAF (RT)	1320	16.4	115	6.2	2.43	.63	21.90	.2687	213.48
Safflower†	SAFMW (RT)	738	----	----	----	----	.51	----	----	----

*Values for these rotations are the average of two replications because REP 3 was planted to millet in 1990 to reduce herbicide carryover problem

†Values for these rotations are the average of three replications

‡Yield value only from REP 1

§Ps, Cs, and Tr measurements are only from REP 2

Note: The true rotation effect can not be seen for 3-year rotations since rotations have only been in place for 2 years

WF=wheat-fallow
WCF=wheat-corn-fallow
WCM=wheat-corn-millet
WSAFM=wheat-safflower-millet
CFW=corn-fallow-wheat
CMW=corn-millet-wheat
CSUN=corn-sunflower
MWC=millet-wheat-corn
MWSAF=millet-wheat-safflower
SAFMW=safflower-millet-wheat
NT=no till
CT=conventional till
RT=reduced till

FIELD EVALUATION OF CORN CROP COEFFICIENTS BASED ON GROWING DEGREE DAYS OR GROWTH STAGE

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CRIS: 5407-13000-002-00D

PROBLEM: Corn evapotranspiration (ET) can be predicted from models based on weather parameters. These models predict a potential ET which is then multiplied by a factor (the crop coefficient) to give estimated ET. Crop coefficients currently in wide use for corn are based on time indexed from date of planting and date of full cover. These time-based coefficients work well under average planting dates and growing season weather conditions, but require periodic adjustment when non-average conditions occur. Crop coefficients for corn based on growing degree days or growth stage can automatically adjust for differences in growth due to non-average weather conditions. The objective of this experiment is to determine if previously defined corn crop coefficients (from Nebraska) based on growing degree days (GDD) or growth stage (GS) are applicable to corn grown in northeastern Colorado, and if these coefficients produce more accurate predictions of corn ET than traditional time-based (ARS) coefficients.

APPROACH:

Three varieties of corn (Pioneer hybrids 3902, 3732, and 3540, with days to black layer of 91, 101, and 109, respectively, and GDD to black layer of 2445, 2559, and 2645, respectively) were planted on three dates (25 Apr 91, 29 May 91, and 18 Jun 91) to a final plant population of about 69,100 plants/ha with 4 replications of each planting date/hybrid treatment. ET was calculated by the water balance method using measurements of soil water content by neutron probe, precipitation, and irrigation water applied. Irrigations were applied weekly by overhead sprinklers to replace water lost from the top 120 cm of the soil profile. Reference crop (alfalfa) ET was predicted by the Kimberly Penman method using weather data collected by an automated weather station located approximately 400 m from the plot area. Reference ET was adjusted to corn ET by three methods:

Method 1. Time-based ARS-Jensen crop coefficients
Method 2. GDD-based crop coefficients from S.E. Hinkle et al.
Method 3. GS-based crop coefficients from S.E. Hinkle et al.

These values of ET were then compared to water-balance-computed ET.

FINDINGS:

The Kimberly Penman equation as calculated by the REF-ET program (R.G. Allen, Utah State University) gives potential ET for an alfalfa crop. The values appear to overestimate potential ET for Akron, possibly due to our weather station being located over unirrigated grass which goes dormant during the summer. When we use potential ET calculated for a grass reference crop (grass ET = alfalfa ET / 1.15), predicted ET agrees more closely with measured ET.

The following figure shows the comparisons of ET predictions for the growing season divided into "before silking" and "after silking" periods. The GDD- and GS-based crop coefficients produced closer estimates of measured corn ET than the ARS time-based coefficients in 7 of 9 combinations of planting date and hybrid before silking, and 6 of 9 combinations after silking. The majority of the ET estimates

from the GDD- and GS-based crop coefficients predicted ET with less than 10% difference from measured ET. The large overestimates of ET by all three methods for the second planting of 3902 and 3732 before silking may be a result of inaccurate measurement of applied irrigation.

INTERPRETATION: Temperature has been previously shown to be the primary climatic variable controlling the vegetative growth of corn that has adequate water, nutrients, and light. Consequently, predicting ET using models based upon an actual crop-growth parameter (growth stage) or a climatic crop-growth-response variable (temperature) has a better basis than time for the dependent variable for crop coefficients. No additional work is required for Method 2 because maximum and minimum temperature are already required to calculate reference ET. The estimation of full cover date and the sometimes uncertain interpretation of actual full cover are also eliminated. Method 3 would require that growth stage be observed at least weekly for each field, but this method is intended to be used only if total GDD for a particular variety in a particular region is not known, then switch to Method 2 when a good value for total GDD is known. Farmers are very receptive to methods that are based on GDD because of an inherent understanding of the close relationship between crop development and temperature, and because of the ease of GDD methods.

FUTURE PLANS: The experiment will be conducted next year and the results will be submitted for publication. Because hourly temperature data were collected during this project, a GDD vs, Growing Degree Hour (GDH) analysis will be made to further refine the accuracy of the corn crop coefficient equations, and subsequent corn ET prediction. This analysis may also increase the understanding of the air temperature and corn growth interrelationship.

GROWTH RETARDANTS PROMOTE DROUGHT TOLERANCE IN CORN (Zea Mays L.)

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CRIS: 5407-13000-002-00D

PROBLEM: Water stress affects all aspects of crop growth and development resulting in reduced yields. Corn has a high water requirement for grain production, but annual precipitation in most areas of the arid and semi-arid regions where corn is grown averages much less than that necessary for maximum yield. Growth retardants (GR) can be used to reduce the water requirement of corn during the vegetative growth stage, when the plant is most tolerant to water stress, so that more water is available during the more sensitive reproductive and grain-filling stages, thereby increasing grain yield under drought stress. The objectives of this study are to determine the effects of two GRs on water use, stomatal conductance, internal CO_2 concentration, transpiration rate, carbon exchange rate water use efficiency, leaf chlorophyll content, leaf protein content,plant height, leaf area index, dry matter yield, and grain yield.

APPROACH: Corn plants receiving no GR (control), a seed-applied gibberellin biosynthesis inhibitor (GBI) treatment, and a foliar-applied ethephon treatment were grown in the greenhouse under optimal water and nutrient conditions. Leaf area (LA), dry matter yield (DW), leaf weighted stomatal density (WSD) and size (SS), leaf chlorophyll (Chl) and soluble protein (Prt) concentration were determined at the six-leaf growth stage. Additionally, gas exchange measurements were made using an automated photosynthesis measuring system to evaluate GR effects on stomatal conductance (Cs), internal leaf CO_2 concentration (Ci), CO_2 exchange rate (CER), transpiration (T), and water use efficiency (WUE=CET/T). Field experiments were conducted during two consecutive growing seasons (1989 and 1990) to determine the impact of ethephon application on vegetative growth, water use, and grain yield of corn grown under semi-arid conditions in eastern Colorado. The 1989 experiment conducted at Akron, CO, consisted of a factorial combination of two irrigation levels (limited and full), two plant densities (53333 and 80000 plants/ha), and five ethephon treatments (no application, and combinations of 0.56 and 0.85 kg a.i./ha with 0.28 kg a.i./ha applied at two growth stages). In 1990, the treatments were altered to include a factorial combination of four plant densities (24700, 37045, 494390, and 61735 plants/ha) and three ethephon rates (0.00, 0.28, and 0.56 kg a.i./ha applied at the six-leaf growth stage) and grown at two locations (Akron and Sterling, CO) under rainfed conditions. Plant height, leaf area index (LAI), DMY, cumulative evapotranspiration (ET), grain yield, and yield components were measured for the treatments.

FINDINGS: In the green house study, LA and DW were reduced approximately 30% by both GR treatments relative to the control. SS was reduced 14% by both GR treatments. SLW and WSD were increased by a maximum of 20-25% by GR treatments. Leaf Chl and Prt concentrations were nearly doubled in plants treated with GR. Cs, Ci, CER, T, and WUE were increased from a minimum of 19% for WUE to 120% for Cs in plants subjected to GR treatments. In all the field studies, ethephon application reduced plant height and leaf area index by 10 to 30% relative to the control. This resulted in reduction in early season evapotranspiration in all studies. Ethephon treatments either had no effect

or reduced yields in 1989 under all irrigation and plant density levels, because of a lack of significant drought stress. However, when drought conditions existed in 1990, ethephon application decreased yields at low plant densities and increased yields at high plant densities, with a maximum of 37% higher yield with the ethephon treatment.

INTERPRETATION: GR treatments increased CER per unit leaf area by increasing stomatal conductance to CO_2 diffusion, concentrating photosynthetic pigments and enzymes per unit leaf area, and increasing leaf carboxylation efficiency. While the GR treatments increased T slightly, they increased CER more, resulting in enhanced WUE at the single leaf level. The smallest grain yield reduction in 1989 was obtained from the lowest ethephon rates suggesting that lower rates would be preferable. This was further confirmed by the 1990 results which showed that the 0.28 kg a.i./ha application rate of ehtephon provided the most positive yield response. GR treatments would appear to have the potential for improving drought resistance in corn and stabilizing dryland corn grain production under the highly variable precipitation regime of the Central Great Plains.

FUTURE PLANS: This project completes Mr. Kasele's PhD. dissertation. The studies will be submitted for journal publication as two manuscripts. Further similar work is being planned for a greenhouse study with winter wheat if funding becomes available.

WHEEL-RIDGE-TERRACE ANNUAL-CROP FARMING

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CRIS: 5407-13000-002-00D

PROBLEM:

New farming techniques and strategies are needed that are sustainable. Cropping practices that use more spring and summer annual crops and use less fallow periods can better utilize the precipitation that falls in the west Central Great Plains. At Akron Colorado, almost two-thirds of the annual precipitation (82 year average) occurs during the late spring and summer months of May (3.04"), June (2.51"), July (2.67") and August (2.03"). During the fallow period, most of the precipitation can be lost to the atmosphere as natural evaporation after a rainfall event (due to no transpiring growing plants) or due to enhanced evaporation due to tillage operations that are done a week or so after a rainfall because the rain causes new weeds to sprout. Therefore, the practice of fallowing the land, although saving moisture from an additional winter's snowfall and being a very successful long-time farming practice, has a low precipitation use efficiency (PUE) when compared to more intensive annual cropping.

Direct annual cropping with no fallow periods, on the other hand, is a marginal farming practice in this region due to the low total annual precipitation and is only successful with reduced tillage and greater surface residues which reduce soil surface water evaporation and runoff, and increase infiltration. However, reduced tillage farming has more problems with weed control, requires a higher level of management (time, knowledge) and timeliness of field operations is generally much more critical. All of these problems have been a major deterrent to the adoption of reduced tillage farming. Therefore, a farming practice using annual cropping (to better use precipitation) but less constrained by the limited total precipitation (less crop per area, more tillage allowed, less dependence on herbicides) could be potentially more successful than traditional crop-fallow rotations. Research in the late 60's and early 70's showed that water harvesting can increase total crop production per total area over conventional farming production during high precipitation years. The objective of this project is to determine if wheel-ridge-terrace farming is a more sustainable way to produce annual crops because of water harvesting and reduced crop area.

APPROACH:

This project will use two separate sets of experimental plots, both using a split-plot statistical design. The two sets are:

1. A wheel-ridge-terrace (WRT) production area using three annual crops grown each year and replicated four times. Plot size is 30' x 100'. The WRT replaces the 2nd and 5th rows when using 6-row equipment, so that 2/3 of the land surface is cropped, and 1/3 harvests water. These plots were established the fall of 1990.

2. Soil profile.comparison (SPC) plots to compare a) wheel-ridge- terraced, 4 of 6 rows cropped (W4), b) ridged-tilled, 4 of 6 rows cropped (R4) and c) conventional flat surface, 4 of 6 rows (F4), and d) 6 of 6 rows (F6) cropped are also used and replicated four times. Plot size is 15' x 120', and were established the spring of 1990.

Organic matter levels in the top 4 inches of soil will be measured in the cropped area before and after the project. Soil moisture content and crop water use will be determined using neutron access tubes. Crop growth characteristics will be monitored and recorded during the crop season. Crop grain yield and biomass production will be harvested and measured. Soil bulk density, fertility, and crop residue mass/cover will be measured annually. The plots will be chiseled to break up any compaction due to the terrace construction and thereafter every 1, 2 or 3 years as subplots.

FINDINGS:

Corn was grown in the SPC plots in 1991.
The corn grain yields were:

W4 = 4863 kg/ha (77.5 bu/ac)a
R4 = 3829 kg/ha (61.1 bu/ac)ab
F4 = 3280 kg/ha (52.3 bu/ac)bc
F6 = 2009 kg/ha (32.1 bu/ac)c

Yields followed by the same letter (a,b,c) are not statistically different. Grain sorghum grown in 1990 reduced soil moisture as evident by the low yields in the F6 plots. The W4 plots harvested 3 to 5 cm (1.2 to 2 in) of additional water during May 1991, and sustained greater soil water status throughout the soil profile during the crop season. These yields are for the cropped area only so for "total area" yields, multiply by 2/3 because in this study the F6 plots will be fallowed once every 3 years, as a comparison to traditional methods.

Corn, soybeans, and sunflowers were grown in the WRT plots in 1991. The corn plots were also divided in subplots with 4 different plant populations, and 2 varieties (91 and 100 day maturities). Corn grain yields ranged from 3450 to 4580 kg/ha (52 to 73 bu/ac) but were not statically different due to population because of high variation between replications. However, the trend was for corn yields to increase with population with 50k to 60k plants/ha (20k to 24k plants/acre) exhibiting the greatest yields. Soybean grain yields averaged 1173 kg/ha (17.5 bu/ac). One of the reps yielded much lower than the others, at 682 kg/ha (10.1 bu/ac). The remaining 3 replications averaged 1337 kg/ha (19.9 bu/ac). An additional 360 kg/ha (5.4 bu/ac) were left in the field either on the ground or in pods on the stubble. Again, multiply by 2/3 to get total area yields, which would be equal or better to the 540 to 880 kg/ha (8 to 13

bu/ac) that has been produced on the station in recent years by conventional farming methods in 38 or 72 cm (15 or 30 in.) rows, with similar field losses. Soybean seed quality in the WRT plots was much better with much fuller and less green seeds. Sunflower yields averaged 1828 kg/ha (1632 lb/ac) per cropped area. Problems with seed metering at planting caused lower than planned plant populations and poor in-row distribution. Average head size was 19.8 cm (7.8 in), so greater plant populations could have possibly increased yields.

INTERPRETATION: This study will determine if wheel-ridge-terrace annual crop farming is a practical and more profitable way of farming in the Central High Plains. The W4 plots in the SPC plot area was able to utilize the extra soil water to produce more corn. And "total area" yields were greater in all of the 4 of 6 row planted plots over the 6 of 6 row plots. However, total area yields were less than dryland corn yields on other parts of the station. It would be preferable to have the wheel ridges farther apart so that less land is out of production but with the same benefits. In future research, I will use 3.3 m (10 ft) controlled wheel traffic, plant in narrower rows, and plant closer to the wheel ridge in order to have a much higher percentage of the total area cropped, which will improve total area yields. The corn population part of the WRT plots showed that corn populations need to be greater for optimum yields. This is significant because if plant populations can be as great as 50k pl/ha (20k pl/ac), then plant transpiration can account for the bulk of crop water use. Corn populations less than this level have less than full cover leaf area, and have progressively more soil water evaporation as a percentage of total evapotranspiration. Soybean yields were significantly greater per cropped area and greater even per total area with much better seed quality over traditionally farmed soybeans. The WRT technique does show promise for improving yields and water use efficiency for at least corn and soybeans.
Potential benefits for WRT farming are: 1) annual cropping (better PUE), 2) water harvesting, 3) more precipitation per cropped area (higher overall soil water status, allowing more tillage and potentially less dependence on herbicides), 4) less wind at the surface to protect young plants and have less soil erosion, 5) more snow catch for surface-harvested crops, 6) controlled traffic, and 7) the raised wheel tracks enable earlier field re-entry after a rainfall. Disadvantages are 1) field equipment must be modified particularly equipment for harvesting crops that are cut at the soil surface, 2) wheel ridges must be maintained, and 3) all of the cropland is farmed every year which may cause timeliness problems if different crops are not grown which spread out field operations.

FUTURE PLANS: The SPC plots will be planted back to grain sorghum with the F6 plot split with 1/2 of the plots left fallow. The WRT plots will be crop rotated with corn after soybeans after sunflowers. Population subplots will be used with corn and sunflowers. The soybean plots will be split with an Austrian Pea & Oats combination for comparison to soybeans. Additional neutron access tubes will be install as needed.

CROPPED-LEVEL-TERRACES IN PASTURES

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CRIS: 5407-13000-002-00D

PROBLEM: New sustainable farming strategies that use an "integrated resource management" approach incorporating livestock with cropping systems are needed. It is through this approach that the level of purchased inputs can be potentially reduced and crop outputs can be better utilized. For example, livestock contribute manure as crop input and grazing reduces harvesting losses and better utilizes the biomass produced. Other proven farming practices can also be used to improve the farming success and long-term sustainability. For example, annual cropping utilizes precipitation better than rotations involving fallow. Water harvesting techniques like bench terraces also improve soil water storage and crop water use efficiency. So combining level terraces, strip cropping within a pasture and annual cropping rotations with integrated crop and livestock practices should inherently be a good, successful and sustainable farming practice. However, this type of farming is virtually unheard of and little or no literature exists on the combination of these four technologies and their interactions. The objective is to evaluate the hydrology, crop growth characteristics, soil properties and the practical aspects of this type of farming.

APPROACH:

Research plots were established on level terraces, bench terraces and on natural slopes (3% and 6%) that were constructed in a native grass field with a water contributing width above each plot equal to three times the width of each level terrace (most optimum width for the contributing slope). Other treatment variables include:

1. with or without deep chiseling to improve infiltration.
2. with or without cattle traffic to see the effect on infiltration.

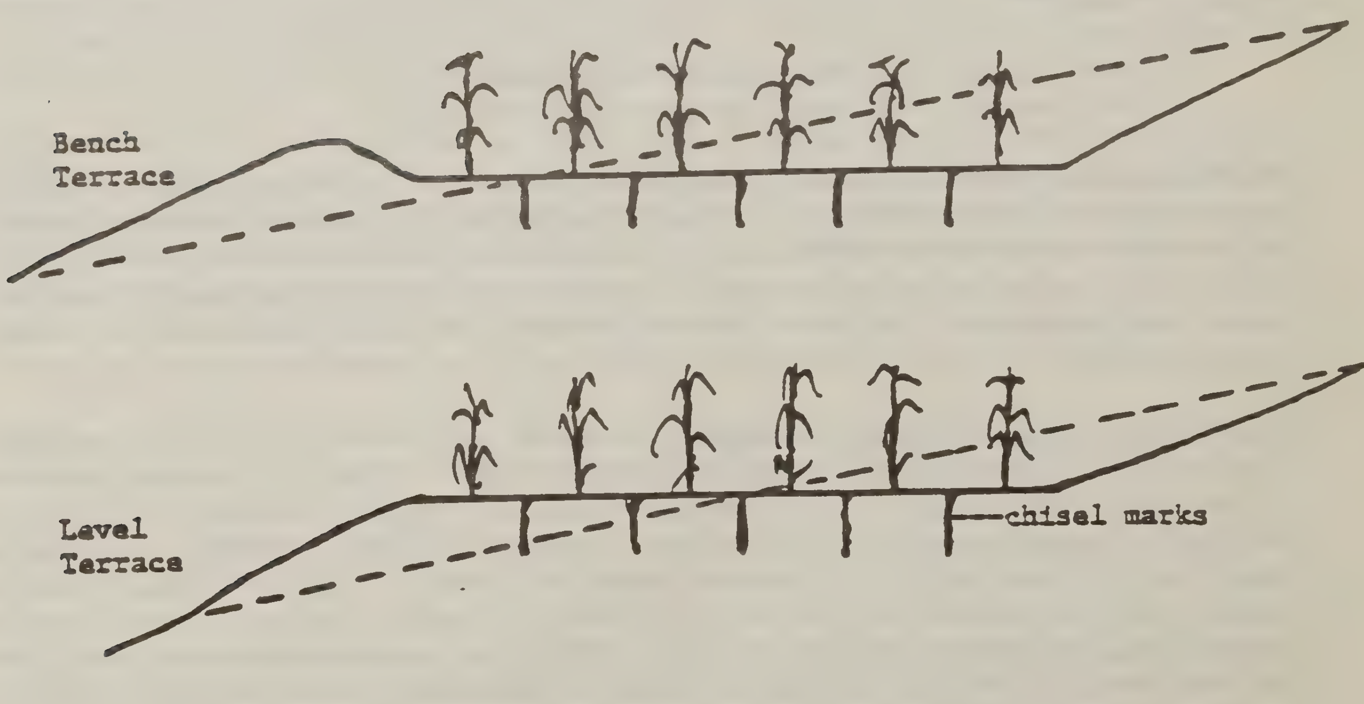
Runoff flumes and recorders are installed each year to measure the amount of water that runs onto the plot area and off of the level terrace and the natural slope plots in order to evaluate the water harvesting aspects of the terraces and the plot treatments. Plots that have no water contributing area (by using a diversion) will also be included and are necessary to evaluate the crop growth and water use with only normal precipitation levels. The plots will be replicated three times. Soil samples from the top 5 cm (2 in) were taken in 1991 for soil organic matter analysis, and will be repeated at the end of the project.

FINDINGS: Previous pertinent information: The terraces were constructed and plots established May-June 1990. The plots were planted to grain sorghum in June 1990 with poor emergence and yields (<1300 kg/ha (<20 bu/ac)) due to dry surface soil conditions. For 1991: Corn was planted no-till in the plots. Lasso and atrazine herbicides were applied preemergence. Nitrogen fertilizer was applied as starter with the planter and as NH_3 side-dress chiseled, for a total of 73 kg/ha (65 lb/ac) of nitrogen applied. The corn was also cultivated before the sidedress chiseling. The grass pasture around the cropped terrace strips was not grazed in the spring of 1991. The areas between the terraces were mowed and baled late June 1991. The 3% sloped area produced 1040 kg/ha (930 lb/ac) and the 6% sloped area produced 627 kg/ha (560 lb/ac) of hay. No rainfall was harvested during the spring and summer of

1991. Because of low rainfall after mid-June, potential grain yields were low so the corn was cut for silage August 22-23, 1991. Silage yields ranging from 6.7 - 19.9 Mg/ha (3-9 tons/ac), at 70% moisture content. Silage yields were only statistically different on the 3 % slope. The bench terrace plot yields were statistically higher than the level terrace or natural slope plots. The chiseled subplot yields were statistically higher than the non-chiseled subplots. The bench terrace berms were sprayed with 2,4-D herbicide twice during early June, and then late August to control broadleaf weeds (mainly, wild sunflower). The deep-chisel subplots were deep chiseled to 38 cm (15") in the fall of 1991, as they were in 1990.

INTERPRETATIONS: The statistical yield differences may not be significant at this point due to non-uniform soil moisture conditions that may have prevailed since construction. Some neutron access tubes were installed in 1991 for biweekly soil moisture measurements. Access tubes have not be installed in most plots yet because of the extremely dry soil moisture conditions that existed initially due to the the previous grass.

FUTURE PLANS: In 1992, the plots will be instrumented with runoff flumes and recorders to measure any surface water runoff. Plans are to graze the pasture with cattle during the spring of 1992, and to plant hay millet in the cropped area. Electric fencing will be used to block off ungrazed cropped areas for comparing infiltration differences with and without cattle. Infiltration rates will be determined with a sprinkler infiltrometer. Another attempt will be made to get neutron access tubes installed in each plot. Surface soil bulk density and crop growth characteristics (height, LAI, growth stage) differences will be measured.



IRRIGATED CORN POPULATION-YIELD STUDY

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CRIS: 5407-13000-002-00D

PROBLEM:

Many agronomic factors and cultural practices can influence corn grain yields. Grain yields can be maximized to near their potential if soil water and nutrients are not limiting plant growth and/or grain production. Maximum potential grain yields then become dependent on the genetic potential of each corn variety, and also dependent on the atmospheric conditions (i.e., heat units or growing degree days) received during the growing season. Plant damage by insects and disease can further reduce potential yields.

Cultural practices can have a direct and variable effect on actual final grain yields. Practices to minimize weed competition for water and nutrients help to maximize yields. Row spacing and plant populations have a direct effect on potential corn yields. Corn yields are increased 5-7% when row spacing is decreased from 102 cm (40") to 76 cm (30"), and are increased another 3-5% if row spacing is decreased to 51 cm (20"). However, 76 cm (30") has evolved to be the most common and practical row spacing when using large farm equipment.

Plant population is probably the most flexible cultural variable that affects final grain yield. Much uncertainty exists among irrigated farmers as to what is optimum plant population. Optimum plant population for each corn variety can be different. Even among varieties with the same maturity, optimum plant population can vary due to vegetative and reproductive growth differences. However, farmers will typically use a particular corn variety for many years. If the optimum plant population for a certain variety can be determined during the first 1 or 2 years of use, then at least that cultural variable becomes known and is no longer a worry or concern for the farmer. The objective of this project is to analyze the physical components of corn plants that determine final grain yield (i.e., leaf area, number of stalks, ears and kernels, and kernel mass) and how these components interact as a function of population. These component functions can then be used to determine optimum plant population, potential grain yields, and what components are most significant for producing high yields.

APPROACH: Three corn varieties (Pioneer 3779, 3714, 3475 with relative maturities of 98, 102, 106 days to black layer development, respectively) were planted at four different plant populations and replicated four times. The corn was grown at two sites on sandy loam and silt loam soils and was irrigated to fully replace crop evapotranspiration losses as calculated by the modified Penman method with appropriate crop coefficients. Physical characteristics and yield components were measured and included leaf area at full cover and the following at harvest: stem count, ear count (1st & 2nd ears), number of rows and columns of kernels per ear (1st & 2nd ears), average kernel mass, yield, moisture content and test weight. The relationships between these variables were graphed, analyzed and mathematical functions developed for them. The functions are then used to predict grain yield, optimum plant population and to determine which components are most significant and critical to producing high yields.

FINDINGS: Corn was planted at seeding populations of 55000 to 87500 plants/hectare (22000 - 35000 plants/acre). From initial analysis, potential grain yields greater than 11500 kg/ha (180 bu/ac) are possible. Water use efficiency, expressed as water/grain mass ratio, ranged from 570 to 700. Leaf area was not limiting for populations greater then 50000 pl/ha (20000 pl/ac) where leaf area index (LAI) values were greater than 3. The number of second ears goes to zero, and the ratio of first ears to stems approaches one as populations increase toward 75000 pl/ha (30000 pl/ac). The ratio of first ears to stems decreases with decreasing population due to more tiller stems. On the first ears, the number of rows of kernels (ear length) decreased with increased population. On the second ears, rows of kernels was essentially constant at 30 rows. Columns of kernels (ear diameter) was not dependent of population and had an average value of 15 for both first and second ears. Kernel mass was surprisingly not dependent on plant population and averaged 0.249 g per first-ear kernel and 0.199 g per second-ear kernel. Multiplying the actual data values of number of ears, rows and columns of kernels, and kernel mass together predicts grain yields within 10%.

INTERPRETATION: The most significant and sensitive component to grain yield is the number of first ears. Potential grain yield is maximized at or greater than 75000 pl/ha (30000 pl/ac) because the number of second ears goes to zero and the ratio of first ears to stems approaches one. This information will allow component analysis and calculations to pinpoint the optimum stem population for maximum yields or maximum profits. Ear/stem ratio should decrease at higher populations because more of the primary stems do not produce ears.

FUTURE PLANS: The same three irrigated corn varieties will be used in 1992, to repeat this experiment at the same two locations. Plans are for 1992 to be the final year for field plots with this project. The results will be written up and presented at the national agronomy meetings, in a crop production journal, and as popular magazine articles.

RIDGE-PLANTING TEMPERATURE EXPERIMENT

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CRIS: 5407-13000-002-00D

PROBLEM: The Central High Plains growing season is significantly shorter than in other regions at similar latitudes due to higher elevations. R. E. Neild found that across Nebraska, there was a 0.87 C decrease in temperature for 1 degree increase in latitude and a 0.52 C drop in temperature for a 305 m increase in elevation. Higher land elevations exhibit lower overall air and soil temperatures throughout the spring-to-fall growing season. For corn grain production, 100-105 day relative maturity varieties are grown near Akron CO at 1420 m elevation, as compared to 115-120 day varieties grown in southeastern Nebraska below 400 m elevation. The effects of higher elevations on decreasing soil and air temperatures can be potentially offset to some extent by microclimate modification of the soil. Soil formed in ridges typically warms up sooner, both daily and seasonally, than flat soil surfaces due to more effective interception of incoming solar radiation. The warmer soil could allow for earlier planting and more rapid germination, and could speed early phases of crop development by increasing air temperatures at the soil surface. Consequently, longer season varieties with greater yield potential could be grown in this area. The objectives of this experiment are to determine:

1. if time of emergence can be shortened with ridged row crops
2. the growing degree day requirements for corn and sorghum emergence
3. the management factors of ridge farming.

APPROACH:

This experiment was initiated in 1989 using corn grown under sprinkler-applied, full irrigation. Grain sorghum and corn were grown in 1990, and grain sorghum only in 1991 on silt loam and sandy loam soils. Both split plot and randomized complete block experimental designs are used with four replications. Soil and air temperature near the soil surface were measured for different tillage and residue treatments. The soil treatments were:

1. no-till, standing corn stubble, flat surface, north-south rows (SS)
2. ridged corn stubble, north-south rows (RS)
3. clean tilled, some residue, flat surface, north-south rows (B)
4. clean tilled, some residue, rows ridged north-south (R)
5. " " " " " " east-west (REW).

Row spacing was 0.76 cm (30 in.). Soil temperature (5 cm below soil surface) and air temperatures (10 cm above soil surface) were measured with thermocouples and recorded with an automated Campbell CR-21X data logger at 1-minute intervals during each day for the period from planting until mid-July (full canopy development). The crops were planted directly on the ridges. Three planting dates (early May, mid-late May, early June) were used to check for any time-of-year temperature differences. Hours from planting to emergence, plant height and vegetative growth stage were monitored to determine microclimate effects on germination and plant development rates. Residue (mass per area and percent

cover) were measured prior to planting. Soil moisture in the top 5 cm (2 in) was measured at least weekly prior to planting and during early vegetative development because soil temperatures and heat movement through the soil surface can be directly affected by soil moisture content.

FINDINGS: Sorghum emergence times were within 1 day for all tillage treatments for the 2nd and 3rd planting, which had planting dates of May 23 and June 12, respectively. The 1st planting (May 9, 1991) had more significant emergence differences. The RS and SS treatment of the 1st planting emerged 3 to 5 days later than the bare soil treatments. The added crop residue cover on the RS and SS plots reduced the warming of the soil, and delayed emergence times. Effects other than soil temperature and accumulation of heat units must be influencing the rate of sorghum emergence, for the differences in accumulated growing degree hours (GDH) did not correspond well with the observed times from planting to emergence. In general, the three tilled treatments (B,R,REW) were similar and accumulated GDH quicker than the RS and SS treatments. There was no consistent soil type effect on rate of GDH accumulation. Grain yields increased with later planting dates. Plantings 1, 2 and 3 averaged 4870, 5595 and 6526 kg/ha (77.6, 89.2 and 104.0 bu/ac). No significant grain yield differences existed within 1st plantings, but within the 2nd and 3rd plantings on the silt loam soil, grain yields for the R and REW plots were significantly higher at 7465 kg/ha (119.0 bu/ac) than the RS and SS plots at 6380 kg/ha (101.7 bu/ac). Consequently, ridge planting increased yields but not due to emergence differences.

INTERPRETATION: Planting grain sorghum in soil covered with heavy residue can delay emergence at early (May) planting dates, but there were no yield differences among the earliest planted sorghum. Farmers should plant after June 1 to obtain higher yields, anyway. Planting sorghum in ridges after June 1 can increase yields but not because of earlier emergence because there were no significant differences in emergence times for the later plantings. However, sorghum planted in ridges is exposed to high winds that can destroy leaves and desiccate young shoots, resulting in stand reductions.

FUTURE PLANS: No further experiments with corn or sorghum will be conducted for this project. The results will be summarized for 2 years of data for grain sorghum and for 2 years of data for corn. Some separate sideline experiments may be conducted for determining soil temperature versus soil depth gradients for the different tillage treatments. This would be done to make quantitative adjustments for the differences in actual planting depth between the different tillage treatments. Soil and air meteorological aspects of this projects are being analyzed and discussed with Dr. J. B. Swan, an agronomist at Iowa State University, who has done similar experiments. Final results will be published in scientific journals and as popular articles in farm magazines.

DRYLAND CORN POPULATION & DRILLED VARIETY STUDY

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CRIS: 5407-12130-002-00D

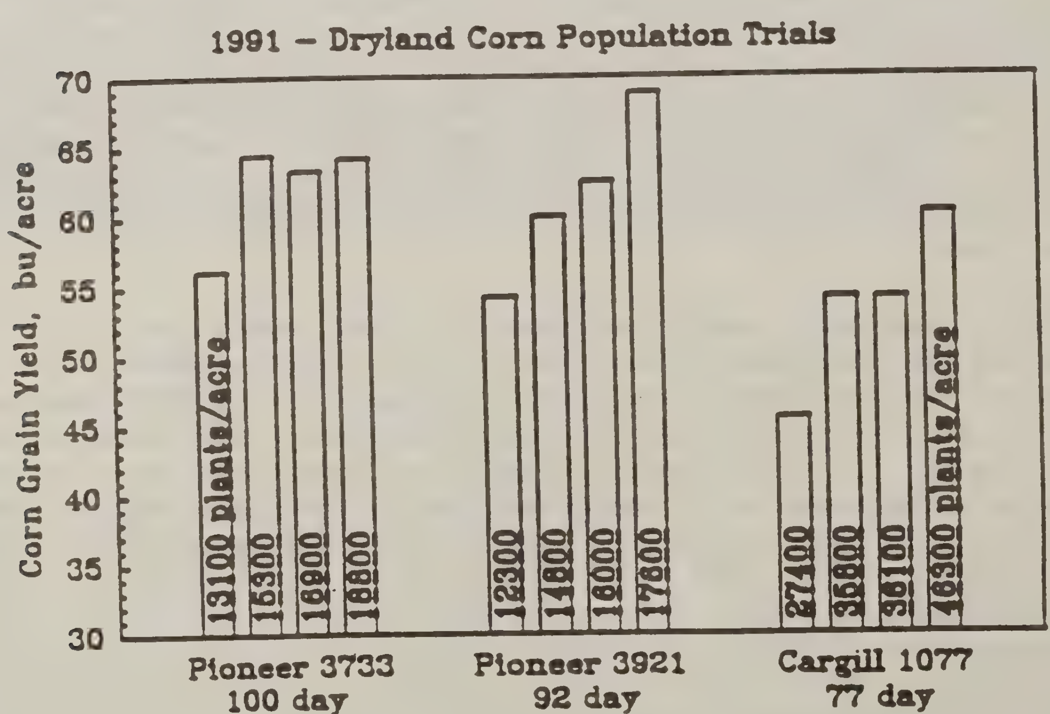
PROBLEM: Optimum plant populations of dryland corn in the west-central Great Plains of the U.S. are still a point of discussion among researchers and farmers. An informal conclusion among the scientists at the Akron research station is that plant populations should be higher for dryland crops than what has been previously used. Research on corn plant populations and grain yield is needed to determine optimum populations for this region. The characteristics of dryland corn growth as a function of population, and the quantitative significance and sensitivity of the various yield components to grain yield needs to be measured also to understand how optimum yields are obtained. Another concern for dryland corn production is the use of dwarf corn varieties. These varieties can be planted with a grain drill and combine harvested with a grain platform head, which has the economic advantage for traditional wheat farmers of not having to buy a row crop planter or a corn head for their combines. The agronomic growth characteristics and the practical, logistical aspects of farming dwarf corn varieties need to be evaluated.

APPROACH: A dwarf corn variety, Cargill 1077 was grown with three traditional corn varieties, Pioneer 3732, 3733, and 3921. These 4 corn varieties have approximate times to maturity (black layer development) of 77, 100, 100, and 92 days, respectively. Using 4 replications, the 4 total varieties were evaluated in split plots, with plant population being the final split. Plot size was 4.6 m by 15.2 m (15 by 50 ft). Row spacing for the traditional varieties was 0.76 m (30 in) and for the drilled dwarf corn variety was 17.8 cm (7 in). Plant populations for the traditional varieties ranged from 30,000 to 45,000 plants per hectare (12,000 to 18,000 plants/acre). Plant populations recommended by a company representative for the Cargill 1077 dwarf corn were 112,000 to 125,000 plants/hectare (45,000 to 50,000 plants/acre). However, difficulties with seed metering on the drill resulted in actual planted populations of 68,500 to 115,700 plants per hectare (27,400 to 46,300 plants/acre). These corn plots were located in an area that was winter wheat in 1990, and all of the corn was planted no-till into the standing wheat stubble. The corn was planted May 22, 1991, and also topdressed with 75 kg/ha (67 lb/ac) of N, as ammonium nitrate.

FINDINGS: The two 100-day varieties from Pioneer yielded 3640 to 4000 kg/ha (58 to 64 bu/ac) for populations of at least 35,000 pl/ha (14,000 pl/acre). The lowest populations yielded 3200 to 3500 kg/ha (51 to 56 bu/ac). For these 2 varieties, grain yields were not significantly different for populations above 35,000 pl/ha (14,000 pl/ac) because the crop ran out of water due to small infrequent rains during mid-to-late summer. The 92-day Pioneer 3921 variety had similar yields for the low and middle populations but had significantly higher yields of 4300 kg/ha (68.8 bu/ac) at 44,000 pl/ha (17600 pl/ac). Overall, the Cargill 1077 dwarf corn had lower yields due to the lower-than-expected plant populations. The lowest population averaged 2800 kg/ha (45 bu/ac) but the highest population averaged a very respectable 3770 kg/ha (60.2 bu/ac). Average plant height of the dwarf corn was 1.11 m (44 in) and there was less than 5 cm (2 in) height difference between the low and high populations. Ear shank height of the dwarf corn was 36 cm (14.1 in) and was not significantly difference among populations. An interesting note is that many of the dwarf corn plants produced double ears at all populations. Ear length ranged from 5 to 15 cm (2 to 6 in.).

INTERPRETATIONS: Higher plant populations for the two 100-day varieties did not increase grain yields due to lack of water. However, the lowest populations did limit grain yield. The 92-day traditional variety performed similar to the 100-day varieties except at the highest population where it yielded slightly higher, which was probably due to less vegetative growth and more grain production before the crop ran out of water. Based on 1991 results, the Cargill 1077 dwarf variety definitely needs to be planted at populations of at least 112,500 pl/ha (45,000 pl/ac), but shows great potential for competing with the traditional longer-season corn varieties. Cargill 1077 has an advantage of drying down much sooner. It was at 15 percent grain moisture content by Sept. 20, and averaged 12.3 % when harvested Oct. 1, 1991. The drill used to seed the Cargill 1077 corn had a diamond-gate, paddle/push wheel type metering system which worked poorly for metering corn seed. The drill would tend to drop the corn seeds in clumps of 3-5 seeds at a time, which resulted in poor seed distribution along the row. The drill was calibrated for higher populations but metered less seed than desired when used in the field. Combine harvesting the drilled corn with a reel with parallel, vertical bats caused some of the ears to be knocked off the plant onto the ground, especially for ears that were still pointing upward. For determining grain yield, the dropped ears were pickup by hand and included in the yield sample. A more traditional reel with fixed bats and/or with wider bats, similar to those used for sunflowers, would probably cause less ears to drop.

FUTURE PLANS: These dryland corn population and variety plots will be repeated in 1992. A different no-till drill with similar row spacing but with flute-wheel type metering will be used for the Cargill 1077 which should work better corn seed. Traditional varieties that have shown good yield potential from seed company and Colorado State University trials may be added to this study, and include: Cargill 4327, Northrup-King 4350, DeKalb 464, and Pioneer 3902.



INFILTRATION IN CROPPING SYSTEMS

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CRIS: 5407-13000-002-00D

PROBLEM:

With no-till cropping systems, macropore development is more abundant within the soil and continuous to the soil surface due to a lack of tillage. Earthworms, nightcrawlers, and other insects have been shown to create large macropores at the soil surface. Insects have also been monitored and shown to chew up little pieces of crop residue and carry these pieces of residue down these macropores into the soil. These factors can increase the porosity and soil tilth of the soil surface, and improve water infiltration into the soil.

Long-term no-till cropping practices can potentially increase worm and insect populations and further improve infiltration. Extensive macropore networks could potentially pose a problem of providing too much "preferential" flow of infiltrated water along these macropore to depths deeper than what a crop can easily use. This preferential flow could actually increase percolation losses and provide an effective conduit for surface-applied chemical to move below the root zone and eventually to the groundwater. The objective of this project is to measure infiltration rates among different tillage practices and crop rotations, and to quantify and qualify the resulting distribution of infiltrated water in the soil profile.

APPROACH: A sprinkler infiltrometer will be used to measure infiltration rates on various established tillage and crop rotations plots in eastern Colorado. A sprinkler infiltrometer is able to make more realistic absolute measurements of infiltration than do single or double ring flood infiltrometer ring tests. The sprinkler infiltrometer will produce drop sizes and velocities similar to natural rainfall in order to provide simulated rainfall as part of the infiltration tests. The machine used to measure infiltration will be referred to as a Rainfall Simulator Infiltrometer (RSI). As of now, Long-Term Tillage (LTT) plots and Alternative Crop Rotation (ACR) plots at the Central Great Plains Research Station (CGPRS) at Akron CO, and Dryland Agro-Ecosystems (DAE) plots near Sterling CO, that belong to Gary Peterson and Dwayne Westfall will be used for this study. All three sets of research plots are currently farmed as dryland rotation plots. The agronomic characteristics of the LTT and ACR plots are described elsewhere in this report. The DAE plots were established in 1985, and have been exclusively cropped without tillage. The crop rotations at the DAE site are: two-year winter-wheat & fallow (WW-F), three-year winter-wheat, corn & fallow (WW-C-F), four-year winter-wheat, corn, millet & fallow (WW-C-M-F), and an opportunity cropping rotation in which the crop that is grown is decided based on available soil water.

FINDINGS: The RSI has been built and is currently being modified for improved operation and performance. Rainfall and runoff demonstrations were conducted at Yellow Jacket CO and the Akron Station. Runoff was measured for notill, and tilled soil with and without residue.

INTERPRETATIONS: None at this time.

FUTURE PLANS: Starting in 1992, infiltration measurements will be made. Plans are being made to build a larger and more portable rainfall/runoff demonstrator using a 7560 liter (2000 gallon) tank trailer.

SUNFLOWER STUBBLE, WIND VELOCITY PROFILES

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CRIS: 5407-12130-002-00D
5407-13000-002-00D

PROBLEM: Sunflowers are a crop for which information is needed on wind velocity profiles above the soil surface within the sunflower stubble after harvest. The Soil Conservation Service is the target agency for this information for use in their wind erosion models. The information is critical for knowing the relationship between plant population, row width, row orientation and stalk height on wind velocity profiles. Information on sunflower grain yield for different plant populations and varieties would also be useful.

APPROACH:

Sunflowers will be planted under sprinkler irrigation in 1992. Variables that affect wind velocity and that will be included in this study are plant population, stubble height, row orientation, and row width. The sunflowers will be grown using conventional agronomic practices. If space is available, different varieties will be planted with the different populations to do field testing for these variables for production purposes. The sunflowers will be combined at various heights to produce various fixed stubble heights. The resulting stubble will be used for wind velocity measurements during the fall of 1992.

Anemometers will be used to measure wind velocity above the stubble for standard wind speed and at various heights above the soil surface within the sunflower stubble in order to determine the shape of the wind velocity profiles for the various independent variables.

FINDINGS: None. This project will commence in 1992 with the establishment of the plots, and with the field measurements.

INTERPRETATIONS: None at this time.

FUTURE PLANS: The wind velocity measurements will be compiled and analyzed. The measured velocities will be non-dimensionalized with above canopy velocity. Velocity profiles will be defined as mathematical equations, as a function of stubble height, row angle to the prevailing wind direction, plant population and row width. If insufficient measurements can't be made during the fall of 1992 for various wind velocity situations, then the project will be repeated in 1993. The wind velocity results will be written up as a format report to the Soil Conservation Service, and as a research publication in a technical journal. The plant population, variety, and grain yield results for irrigated sunflowers will be published as a technical paper and as popular articles.

SOYBEAN GROWTH CHARACTERISTICS

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CRIS: 5407-12130-002-00D
5407-13000-002-00D

PROBLEM: Soybeans have been shown to be a poor dryland crop in the west central Great Plains due to poor water stress characteristics. Irrigated soybeans work well in a corn and soybeans rotation which has increased in popularity in the more traditional irrigated corn growing areas of eastern Colorado and western Nebraska and Kansas. However, the standard maturity groupings for soybeans do not adequately describe the maturities that can be realistically grown on the higher elevations of the western Great Plains. Much shorter maturities must be grown than predicted by the standard maturity groupings, which appear to be dependent upon not only latitude but also elevation. An estimate of maturity grouping for elevation is needed. Growth characteristics of soybeans for different maturities, populations and water (rainfall and irrigation) need to be measured and evaluated in order to determine optimum maturity lengths and populations for both dryland and irrigated situations. Seed quality can also be severely reduced in dryland soybeans. Yield component analysis can be used to determine these optimum maturities and populations, and the sensitivity of the components to final grain yield.

APPROACH: Four varieties of soybeans of different maturity lengths (Pioneer varieties 9162, 9202, 9241, and 9272 with relative group ratings of 1.6, 2.0, 2.4, and 2.7, respectively) were planted at four populations ranging from 275,000 to 500,000 plants per hectare (110k to 200k plants/acre) across a water gradient using a solid-set, line-source sprinkler irrigation system. There were 4 replications of each plot. Irrigation amounts were measured with catch cans across the irrigation gradient. Crop growth characteristics were measured during the growing season and included: growth stage, plant height, lowest pod height, numbers of nodes, number of pods, seeds per pod and stem branching. At harvest, seed samples were taken to determine seed quality (seed mass and number of green seeds). Yield component analysis as a function of maturity, population and water will be used to determine optimum maturity and population for both irrigated and dryland soybeans, and the minimum practical water requirement for dryland soybeans. All soybeans were inoculated with nitrogen fixing bacteria prior to planting.

FINDINGS: Irrigation applied across the water gradient ranged from 29 to 180 mm (1.14 to 7.08 in.). Differences in plant height, number of nodes, branching, number of pods, seed size, and number of green seeds were observed across the water gradient, maturities and populations. All of these parameters were measured in the field in addition to growth stage, lowest pod height, seeds per pod. Analysis of this data is not complete at this time. Conclusions will be made after a second years (1992) data is collected and analyzed.

INTERPRETATIONS: None at this time.

FUTURE PLANS: This experiment will be repeated in 1992 with the same four varieties and populations across similar water gradient levels.

CROP RESIDUE DECOMPOSITION

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CRIS: 5407-12130-002-00D
5407-13000-002-00D

PROBLEM: Not enough data exists on the reduction and decomposition of crop residues due to time, tillage and weather factors. The Soil Conservation Service in Colorado has targeted this issue of crop residue changes through a season as an important issue for the proper determination of residue levels in regard to the Conservation Compliance program within the 1990 Farm Bill. As dictated in many individual farm conservation plans, 30 percent residue cover must be maintained. There is still much uncertainty as to what amount of tillage can be done between harvest of one crop and the planting of the next crop, and still maintain at least 30 percent residue cover during the high wind erosion period between November and April. Rainfall and the resulting surface soil moisture can have a significant effect on the rate of residue decomposition. Rates of decomposition determined in the climatically-wetter regions of the eastern half of the U.S. are probably not appropriate for the semi-arid regions of the western Great Plains. The release of nitrogen and other nutrients from crop residues is also an important management consideration that needs to be defined quantitatively with time. The objective of this project is to measure and determine the parameters of residue decomposition for 3 crops, different tillage systems, and different rainfall levels (simulated with irrigation).

APPROACH: Corn, soybean, and sorghum residues currently exist within a solid-set irrigation system and will be used for this project. None of the cropped areas were tilled after harvest in 1991. Beginning residue levels (mass and percent cover) will be measured. Plots will be established across an irrigation gradient to simulate different rainfall water regimes. Different strips of tillage plots across the gradient will be established as soon as possible during the spring of 1992. The exact type and number of tillage systems will be determined based on common practices in Colorado and recommendations from SCS. The residue plots will not be cropped in 1992. However if space is available, cropped areas (corn and wheat) will be used as plots also because crop cover and shading has been shown to affect rates of residue decomposition. The amount of solar radiation reaching the soil surface will be measured with line quantum sensors or estimated from leaf area measurements. Residue mass and percent cover will be measured periodically during 1992. Rainfall and irrigation amounts will be measured with catch cans. Specific details of the tillage operations (type, depth, speed,...) will be noted and recorded. Soil temperatures and moisture in the top 10 cm (4 in.) will be measured. The chemical characteristics of residue decomposition will also be measured using analytical laboratory techniques on field collected samples. Attempts will then be made to describe and model the physical and chemical characteristics and processes of residue decomposition for these three crops.

FINDINGS: The corn, soybean, and sorghum cropped areas were left untilled in 1991. Plots will be established in the spring of 1992.

INTERPRETATIONS: No data has been collected yet. No interpretations at this time.

FUTURE PLANS: Plans are to conduct these experiments for at least two years, in 1992 and 1993. The information will be made available to the SCS and will be published in agricultural journals.

METHOD DEVELOPMENT FOR EVALUATION OF C AND P POOLS TO ASSESS SOIL QUALITY

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CRIS: 5407-12130-002-00D

PROBLEM: Over the past few years much attention has been given to the loss of native soil organic carbon, nitrogen, and phosphorus because of cultivation. In the semiarid areas of the Great Plains, this concern is even greater because of the high erosion hazard associated with plowing the native grasslands. This decrease in productivity and soil quality is usually associated with a significant loss in soil organic matter (SOM) and soil aggregation. Total pools of organic C and P in croplands are sometimes inadequate as predictors of trends in soil deterioration because they lack sensitivity over the short term (1 to 3 years). A need exists to develop methodology to assess soil quality changes and direction of change. The specific objective, therefore, was to develop sensitive organic C and P methods to assess soil quality, and consequently, soil productivity in croplands. Methodology will be based on correlations with measures of soil microbial activity such as the phosphatase activity, and on water- and base -soluble organic C and P, and carbohydrate-C (binding for aggregates) which, hopefully, may integrate losses due to erosion, decomposition, and gains due to organic matter inputs from previous cropping.

APPROACH: Soils from 5 alternate cropping plots (no-till Fallow-Winter Wheat and Winter wheat-Fallow, Conventional-Till Fallow-Winter wheat and Winter Wheat-Fallow, no-till grass) and from adjacent native sod were used to test extractability of organic C and P from water (high soil/solution ratios) and dilute base solvents (NaOH with and without EDTA). These pools were regressed against total pools, established methods for labile pools, and selected measures of soil microbial activity such as the phosphatase activity for biological correspondence. Where possible organic C and P were measured in the extracts, and color intensity of basic extracts was determined as a measure of total C along with established methods for total organic P.

FINDINGS: Extractants for a measure of soluble C tested were: water, 0.5 M $NaHCO_3$, 0.5 M NaOH, and 0.5 M NaOH after treatment with 1 M acid. Total C was estimated from colorimetric procedures based on dichromate reduction and on extract color absorptivity (NaOH and NaOH plus EDTA) at 550 nm. For total C, results from cultivated rotations (10 sites) showed about a 40% loss compared to adjacent native sod. Soluble organic C results were variable with the different base extractants for cropped areas even though all methods consistently gave higher values for the grass site. Measurements for water-soluble and residual organic C (measured on the base after acid pretreatment) showed some correlation with the phosphatase activity, and may be promising to monitor soil quality changes. Results for extraction of total organic P, and labile inorganic P with basic EDTA showed good correlations with existing methods such as the bicarbonate procedure and the acid/base sequential extraction procedure for total organic P.

INTERPRETATION: Preliminary results with limited sampling showed that organic C measured in aqueous extracts of high soil/solution ratios may reflect sensitive short-term changes. This was evident in the fact that although fallow systems showed slightly higher total organic C than wheat-based systems, the water-soluble organic C (and inorganic and organic P) in the fallow systems were significantly lower

probably because of mixing (plowing) and increased aeration. Residual organic C showed good correlation with the phosphatase activity, and may be a good measure of the soil's stability or resistance to erode.

FUTURE PLANS: Methodology development needs to continue with many more tillage and rotation combinations, and with soils that provide distinct differences in organic matter such as soils in a catenary sequence, and soils in various phases of grass reestablishment (Conservation Reserve Program). Emphasis will be placed on correlations with water-soluble and residual organic C. Carbohydrate-C will also be determined as an indicator in aggregate stability. The P dynamics in these extracts will also be monitored.

NITROGEN RESPONSE OF SPRING AND WINTER CANOLA

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CRIS: 5407-12130-002-00D

PROBLEM: The United States currently imports over 600 million lbs of canola annually. This represents a potential production acreage in the United States of approximately 300 to 400 thousand acres. Canola has been identified as a potential oilseed crop for the central Great Plains. The question is whether canola production can be successful and sustainable in the Central Great Plains. Much of the basic agronomic knowledge required to make canola a successful crop option in the Central Great Plains is uncertain. Basic management information such as variety selection, nutrient requirements, heat unit requirements, planting date and planting depth have not been established for canola in our region.

APPROACH:

In this study the N response, and yield potential of 4 spring varieties (Westar, Parkland, Tobin, Global) and 3 winter varieties (Touchdown, Glacier, Crystal) will be evaluated in a split-block designed field experiment with 4 replications with varieties as main plots and nitrogen (N) rates (0, 40 and 80 lbs N/acre) as subplots (strip-plots). Individual experimental units are 30 (9.144m) by 50 (15.24m) ft. The experiment is established on a Platner silt loam under two different previous crop-management histories at the Akron Research Station. Site one is established in wheat stubble, site two is established in fallow ground previously planted to dryland corn. On August 15, 1991 all plots were top dressed with 40 lbs P_2O_5 as 0-46-0 and N (N as ammonium-nitrate) treatments were applied at this time. All fertilization was done using a Barber spreader. Winter varieties were first planted on August 30, 1991, in moist soil caused by a half inch rain on August 28, 1991. Because of dry conditions following planting most of the canola that germinated was dead by the first week of October. Winter varieties were replanted October 9, 1991, 1 inch deep, at a seeding rate of 6.5 lbs of seeds per acre (approximately 650,000 seeds/acre) using a Tye no-till-disk drill. Spring varieties will be planted when soil temperatures reach an average temperature of 4°C (39.2°F) on about the last week of March or the first week of April 1992 depending on soil moisture conditions.

Three additional winter varieties (Capricorn, Liborious, and cc-349) were planted in non-replicated strips along side the replicated experiment for qualitative evaluation.

FINDINGS: Due to an extremely dry fall, winter varieties planted October 9, 1991 did not germinate and/or harden in time to survive the cold snap Akron received the second and third week of October. The record low temperatures of the last week of October 1992 were severe enough to have damaged and/or eliminated much of the winter canola production from Colorado to Montana (Personal Communication Dr. Duane Johnson CSU).

INTERPRETATION: It is too early to make meaningful interpretations since the spring varieties will not be planted for another 6 weeks or so.

FUTURE PLANS: We would like to continue the experiment for a total of at least 3 years as a measure of environmental variability.

P, C, AND MICRONUTRIENT DYNAMICS UNDER ALTERNATE CROPPING AND TILLAGE SYSTEMS

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PROBLEM: The dominant dryland cropping system in the Central Plains is the two-year cycle of conventional-till (CT) winter wheat and fallow (WW-F). Numerous studies in the Great Plains have shown that this system may not be the best for efficient utilization of water and nutrients. Additionally, if one could introduce another crop or two into the rotation system without a deterioration in soil productivity (No-till (NT) systems) or weed infestation (Reduced-till (RT) systems), then farm income can be obtained 8 or 9 times in 12 years as opposed to 6 in a conventional wheat-fallow system. The challenge then becomes one of choosing the right set or sets of rotations, that are economically desirable and simultaneously maintain or improve soil productivity. This is the objective of the station team research. My specific objectives are: to monitor changes in organic matter, P, and Zn under selected alternate cropping (one to four-year rotations) and tillage (NT, RT) systems as compared to the standard clean-till wheat-fallow rotation.

APPROACH: The study is located at Akron CO on a Weld silt loam. Three replications of 60 combinations and permutations of cropping and rotation sequences exist (See report by Halvorson, Hinkle, Nielsen, Anderson, Bowman, and Vigil for treatments). Extensive research will be conducted on 18 of the 60 for changes in organic matter and nutrients. These combinations are: CT and NT WW-F and F-WW (4), NT grass (1), NT millet-WW (2), NT corn-F-WW (3), NT and RT corn-F-WW-millet (8).

FINDINGS: Soil samples have been collected from all 180 sites. So far available P ($NaHCO_3$) and total organic P analyses have been completed on the top 7 cm. An evaluation of the sodium bicarbonate (NaH-Pi) data (fertilizer P was applied to all sites) showed large variability in the three blocks (reps). Average and standard deviation (mgP/kg soil) for block 1 was 25.2$\pm$ 9.5, for block 2, 20.0 $\pm$ 8.2, and for block 3, 18.6$\pm$ 10.6. Block one had only one site under 12, block 2 had 6, and block 3 had 18. Total organic P (TPo) values were also highly variable, 88$\pm$14 for block 1, 79$\pm$12 for block 2, and 72$\pm$8 for block 3. Preliminary data on 5 sites (Table 1) of two cropping combinations only showed an increase in organic C from the grass treatment over conventional-till and no-till wheat-fallow and fallow-wheat systems. Wheat-fallow systems averaged about 0.6% C, while the grass system averaged 0.7%, and the adjacent native sod about 1.2%. Data showed that about half the organic C and about two-thirds of the organic P have been lost (uptake, decomposition, erosion) since these sites were put into cultivation.

INTERPRETATION: Large variability in P values exists among replicates, but this was not the case for the few organic C values determined on the cropped sites. As more data are collected, and more compositing of cropped and fallow , conventional and no-till are done, changes in labile forms of OC and P may become more evident. Significant results from study may require 3 to 5 years since complete cycles range from one to four years.

FUTURE PLANS: Plans are to finish total soil C, P, and Zn analyses on all 180 sites at the 0 to 7 and 7 to 15 cm depths, and to determine labile pool changes of C, N, and P for 54 sites which will be extensively studied. As other data show interesting trends (pH, Cation exchange capacity), or lack thereof, sites may be added or dropped.

Table 1. Organic Carbon (OC) and P contents and soil reactions under five alternative cropping systems and adjacent native sod.

Treatments		pH	OC_t	TPo	Water-soluble			NaH-Pi
					OC	Pi	Po	
			--mg/kg--		----mg/L----			mg/kg
Conv. Till	WF	6.75	5.56	0.096	52	0.89	0.71	16.0
	FW	6.02	6.07	0.094	28	0.55	0.28	18.2
No Till	FW	6.95	5.85	0.103	32	0.55	0.13	22.9
	WF	7.04	5.73	0.086	46	1.75	0.55	25.4
No Till Grass		6.50	6.89	0.100	63	1.37	0.72	21.2
Native Sod		6.91	11.76	0.145	66	0.74	0.70	15.2

P and Zn DYNAMICS IN NO-TILL WHEAT AND CORN

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PROBLEM: No-till systems usually conserve more moisture than clean-till systems, especially when weeds have been controlled. The extra available water invariably results in greater yield benefits from N and P fertilizer, with corn requiring more water and fertilizer than wheat because of its higher dry matter production (40 bushel dryland wheat requiring about 83 kg N and about 12 kg P, with 75 bushel dryland corn requiring about 100 kg N and 18 kg P / ha). The role of water and nitrogen is being studied for efficient use. As cropping continues, other nutrients such as P and micronutrients which are seldom replenished, may become deficient. This need becomes even greater in the eroded areas of the Plains where P is chemically fixed by free lime, and where high P applications may also induce Zn and Fe deficiencies. The objectives of the research, therefore, are to evaluate the need for P and micronutrients in no-till wheat and corn, to measure changes in forms and availabilities of P with time, and to predict yield responses for these nutrients.

APPROACH:

Two sites have been selected, one at Peetz, CO for evaluation of no-till wheat (See report of Halvorson and Havlin for plot design and treatments), and one at Akron, CO on a Platner loam soil for continuous no-till corn. Only the broadcast sites with N (40 sites) are been studied at Peetz. Treatments for the corn study are: four replications with randomized NP factorial (4 N x 5 P for a total of 20 treatments per replication). Nitrogen applications were: 0, 40, 80, and 120 lb/Ac of N as NH_4NO_3, and 0, 30, 60, 90, and 120 lb/Ac of P as triplesuperphosphate (0-46-0).

For the wheat study soil samples were taken in spring 1990, and from previous collections by Halvorson and Havlin. Whole wheat plants were harvested on March 19, April 1, April 16, and June 10. Total and available P pools were determined on the soils, and total N, P, and Zn on the plants. For the corn soil samples were taken from all 60 sites in May, and whole corn plants were harvested on June 19. Grain was harvested on Oct 11. Analyses were the same as those for wheat.

FINDINGS: Soil available P has been determined on all 1990 soil samples for both wheat and corn. Plant P has also been determined on all wheat tops (Table 1) and corn tops and grain. Wheat P concentrations from seasonal sampling showed consistently much higher P concentrations at the higher P rates. Zinc content has been evaluated on the corn tops and grain, but not on wheat. Corn showed similar results to wheat for P fertilization, but yield increases were due to N primarily.

INTERPRETATION: In both the corn and wheat studies, soil levels of available P were high, average for 0 P in the wheat being about 15, and that for corn about 28. This high P level for corn made yield response negligible except where N was added (zero N, 43 bushels; 120 N, 52 bushels). For wheat and corn, generally, as P levels increased P concentrations in tops increased. Zinc levels appeared to be marginal in the corn (about 18 ppm for grain, and about 21 for young leaves).

FUTURE PLANS: We will continue to monitor changes in P and Zn in wheat and corn. Sampling will coincide with defined phenological plant stages, and soil will be sampled at those times also. The initial soil samples (1986) will provide the basis from which changes will be evaluated for wheat. Corn site was previously part of an entomological experiment with wheat to assess high P effects on Russian wheat aphid infestation. Future changes will be assessed relative to the 1991 sampling.

Table 1. Soil P and seasonal P concentrations (1991) in no-till wheat (whole tops) as a function of P fertilization and placement.

Placement	$NaHCO_3$-Pi	P levels	3/19	4/1	4/16	6/10
		kg/ha	---------Plant P, mg/kg---------			
Incorporated	20.4	0	2.42	2.48	2.17	2.60
	18.4	30	2.55	2.74	2.38	2.44
	23.0	60	2.68	3.28	3.02	2.73
	24.4	90	2.99	3.21	2.88	2.97
	21.7	120	3.12	3.17	3.29	2.88
Broadcast	10.7	0	2.50	2.32	2.03	2.67
	14.6	30	2.26	2.53	2.33	2.28
	27.8	60	2.79	2.83	2.48	2.59
	27.7	90	2.74	3.02	2.26	2.85
	29.9	120	3.17	3.11	2.98	2.76

INVESTIGATION OF BASE TEMPERATURE AND PLANTING DEPTHS OF SPRING CANOLA AND SAFFLOWER

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PROBLEM: Canola and safflower have recently been identified as potential alternative crops for the Central Great Plains. Very little information exists in the literature concerning the heat unit requirements for their growth, development, and production. An understanding of the match between their physiological heat unit requirements and the historical record of a given crop producing region will aid in the successful match and development of appropriate varieties and management practices for a given region. Quantification of the heat unit requirement for germination and physiological development of canola and safflower can be used to help guide producers, researchers and extension personal in making informed management decisions with respect to optimal spring planting dates, time of expected seedling emergence, time required for the onset of flowering, and the onset and duration of the grain filling period. The heat unit quantification of canola and safflower can potentially aid in the selection of the proper variety for a given location in the Central Great Plains and aid plant breeders in the selection and development of appropriate genetic material for a given location. The objectives of this study are to develop models to predict seedling emergence characteristics as a function of soil temperature and planting depth, and to provide data for the development of heat unit requirements for the germination of these crops. Models will be used as an aid to guide producers in early season management of these crops.

APPROACH: In this first of a series of potential investigations we examined the amount and rate of germination of two spring canola varieties (Tobin and Global) and one safflower variety (S-208) as affected by planting depth and temperature. Individual 500 ml clear plastic pots were marked and filled with soil at a wet bulk density of 1.0 with either Platner silt loam or Weld silt loam. The experiment was conducted at constant soil water contents of either 16 or 20 percent gravimetric water content. Individual pots marked at various depths were partially filled with moist soil to a specified mark on each pot. Twenty seeds were placed at equidistant spacings on the surface of the soil and then covered with soil to the appropriate depth. Seeds were planted at 5 different planting depths of 1, 2, 2.5, 3, or 4 cm (one depth and variety per plastic pot). A complete replication of one soil type at one soil water content consisted of 40 pots (2 varieties, by 5 planting depths, by 4 temperatures). The appropriate individual pots were then placed into separate constant temperature incubators at 4, 8, 12, and 16°C (39.2, 46.4, 53.6 and 60.8°F) which corresponds to early spring temperatures in the Central Great Plains during the months of March and April. The complete experiment was replicated 2 times. The number of seeds germinated in each pot were counted on a daily basis initially and then twice daily during the rapid germination phase at 16 and 12°C. Germination measurements and accumulated heat units were determined for a 55 day period from December 17, 1991 to February 12, 1992.

FINDINGS: Germination of canola was essentially complete for all depths 12 days after planting at 16°C, 22 days after planting at 12°C, and 30 days after planting and at 8°C. Measurements at 4°C are continuing. We measured up to 95% germination at the shallower depths at 16°C by day 12 with an average of near 68%, at 12°C we measured up to 90% germination at the shallower depths with an average near 65% by day 22. At 8°C we measured up to 70% germination with an average of 50% on day 30. At 4°C we measured up to 60% germination with an average of 20% by day 50. We are

continuing to measure germination at 4°C. It was interesting that Tobin, a compestrus type of canola which was smaller in seed size than Global had a higher emergence rate than Global at the deeper soil depths. Safflower data is currently being collected, therefore no analysis of data has been performed yet.

INTERPRETATION: Preliminary analysis indicates we might expect severe reductions in stand when canola is planted at soil temperatures that will be sustained much below 8°C. This preliminary analysis suggest that spring canolas should be planted not much earlier than the last week of March and that increased seeding rates may help to off set the expected loss in stand if planted earlier when temperatures are cooler. Preliminary observations of safflower suggest similar trends.

FUTURE PLANS: We have found that canola and safflower will germinate at temperatures of 4°C. The study will be repeated at 0 and 2°C to determine base temperature using the method of Lawlor et al (1990). Experiments to quantitatively characterize the vegetative and reproductive stages of canola will be pursued using the methods described by Klepper et al. (1983). The germination data collected will be used to fit linear and nonlinear regression models to describe the germination rates and amounts as described by Scott et al. (1983) as a function of temperature and planting depth. These relationships will be tested (validated) under field conditions and then used to help guide producers in the early spring management of canola. The heat unit approach used in this series of studies allows the data developed at this station to be transferred to other locations.

CARBON AND NITROGEN MINERALIZATION FROM DECOMPOSING CROP RESIDUES

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CRIS: 0500-00026-031-00D

PROBLEM: The amount of NO_3-N entering groundwater supplies is a national concern. The NO_3-N entering ground water comes from N mineralized from native soil organic matter, organic amendments, crop residues, and from fertilizer applied in excess of the amount required for sustainable crop yields. The excess NO_3-N (particularly the mineralized NO_3-N) is not always in synchronization with maximum crop uptake and is therefore potentially leachable. Most laboratories recommending N fertilizer either ignore or simply guess at the amount of N mineralized from organic sources. The problem lies in the complexity of N turnover which is affected by variable soil, and residue characteristics, and variable soil environment from year to year. Simulation models which mimic the processes of organic N turnover, crop N uptake, and soil water movement, allow for the integration of variable residue, soil, and environmental factors and can be used to predict these processes.

APPROACH: The objective of this study is to evaluate and improve existing simulation models to accurately predict: (i) seasonal N dynamics under field conditions. (ii) available N in synchronization with crop uptake (iii) N available for leaching. The MINIMO subroutine (The mineralization immobilization subroutine for the EPIC, and CERES-maize models) has been tested for its ability to mimic the mineralization of N from ^{15}N-labeled crop residues under field conditions. In those studies the simulation model over predicted the amounts of N mineralized. Rate constants for decomposition of plant materials in MINIMO have been derived from laboratory studies with finely ground plant materials mixed with soil. Crop residues decomposing under field conditions are usually not finely ground. The over prediction may partially be related to rate constants in MINIMO. Laboratory investigations of N mineralized from the surface soil of a typical Platte Valley soil mixed with corn residues of variable N concentration and 5 particle sizes has been under way since June of 1990. Residue soil mixtures are incubated and periodically leached with 0.01 M $CaCl_2$ using a modified Stanford and Smith approach. The collected data will be used to modify the MINIMO model to take into account crop residue condition in the field (i.e. stalks chopped vs disked, or left on the surface).

ACCOMPLISHMENTS: The amount of N mineralized (as measured by the accumulated inorganic N) decreased with decreasing residue particle size for corn leaf residues (C/N ratio of 25). This relationship between leaf particle size and the amount of inorganic N accumulated was consistent for all 4 particle sizes. For leaf particles ground to less than 2 mm, only 25% of the residue N was recovered 174 days after residue incorporation. For larger leaf particles 40 mm long by 10 mm wide up to 75% of the residue N was recovered 174 days after residue incorporation. For corn stalk particles (C/N ratios of 65 to 70) we measured net immobilization during the entire 174 day incubation. Less immobilization was measured for the largest corn stalk particle sizes. A follow up study was designed to look at microbial biomass pools and denitrification. This study has not been completed primarily due to not yet having the lab set up at the Akron station for measuring CO_2 and N_2O from closed containers. At the present time a procedure for measuring NH_4-N from $CaCl_2$ leachates needs to be developed at the Akron station. Procedure development will be done this spring. The other methods, hardware, and procedures for doing this type work are being developed for the Akron station and the study will be conducted this summer (1992).

INTERPRETATION:

Even though the actual amount of accumulated inorganic N was less with the smaller particle sizes we suspect that the actual decomposition of the smaller residue sizes was greater. It is reasonable that the greater surface area with the smaller particles would provide a greater opportunity for microbial attack. We suspect that much of the N not accounted for during this decomposition may be either immobilized as microbial N or lost through denitrification. Denitrification is supposed to be minimal at water filled porosities less than 60%. This experiment was conducted at water filled porosities of 55% or less. However it is possible that the soil micro-environment around individual particles may go anaerobic if decomposition proceeds rapidly enough. This would void the 60% water filled porosity rule of thumb for the decomposition of crop residues of sufficiently small size.

The wide C/N ratio of the corn stalk residue resulted in net immobilization for 174 days at optimum moisture and near optimum temperature. From other research we have conducted we know that decomposition under field conditions in the midwest proceeds approximately 30 to 50% slower than under laboratory conditions. Under field conditions a net immobilization of corn stalk residues may be for a year or more.

FUTURE PLANS: Follow up research will be conducted to quantify the amount of denitrification in this system. We will continue additional incubation experiments designed to determine the amount of N that has been converted to microbial biomass N and the amounts of CO_2 produced during decomposition. We have begun to fit first order rate constants to the accumulated N mineralized data. The final step will be to run this data through the simulation model to further test its ability to accurately simulate the measured N transformations and residue decomposition. The developed relationships will be used to improve the existing simulation model which will then be tested under field conditions for its ability to accurately quantify N and C cycling in Great Plains soils. A final test would be to use the model to improve existing fertilizer recommendations which at this time do not accurately take into account the cycling of C and N.

AN EVALUATION OF NITRIFICATION INHIBITORS AND PRECISION PLACEMENT OF LARGE UREA PELLETS FOR IRRIGATED CORN

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CRIS: 0500-00026-031-00D

PROBLEM: Efficient use of fertilizer N sustains crop yields, reduces producer expenditures for fertilizer, and minimizes environmental contamination. Recent research with irrigated corn in Colorado and wheat in North Dakota has shown significantly improved N fertilizer uptake when the nitrification inhibitors CaC_2, and DCD (dicyandiamide) are mixed with urea. In Kansas with cool season grasses, large urea granules significantly increased N uptake when compared with conventional urea fertilizer. Research done in Texas where fertilizer N was placed only in the non-irrigated rows of irrigated crops showed greater N recovery and therefore less potential for N leaching losses than conventionally placed fertilizer N. In this study a combination of these products and placement strategies are being tested to maximize the fertilizer use efficiency of irrigated corn.

APPROACH: The objective of this study is to determine the best combination of inhibitor and fertilizer placement in the non-irrigated row for irrigated corn to increase N use efficiency and reduce fertilizer N lost to leaching. The study was initiated the spring of 1990 on a Hall silt loam near Shelton, Nebraska at the MSEA site. Large 1.7 g urea pellets were placed 10 cm deep and 10 cm away from rows of V1 stage corn (1990) and V3 stage corn (1991) at 20 cm intervals along the row. Nine treatment combinations of large urea pellets with or without two nitrification inhibitors (CaC_2, or DCD) were applied at N rates of 40, 80, or 120 kg N/ha. Conventionally banded urea and a check with no fertilizer applied were also included in the experiment. Microplots within larger field plots were established at all treatment combinations for the 40 and 120 kg N/ha rates. These received ^{15}N labeled urea to allow for estimation of fertilizer N recovery and plant N derived from fertilizer. Inorganic N levels in the zone of fertilizer application were monitored 7, 32, 43, and 96 days after fertilizer application. Chlorophyll meter readings, leaf punch N, total plant N, and total plant dry weights were measured 30, 34, 45, 59, 76, and 119 days after emergence.

ACCOMPLISHMENTS:

Soil NO_3-N levels were significantly less in the zone of fertilizer application of inhibitor treated plots one week after fertilizer application (during early vegetative growth) than in plots without inhibitors. At 32 days after N application both inhibitors maintained significantly higher ammonium N than plots without inhibitors. At 43 days the effect of the CaC_2 inhibitor on soil ammonium-N was not measurable in the zone of fertilizer application. At 43 days DCD was still maintaining approximately 65% of the ammonium N for either CaC_2 treated plots or plots without inhibitor. The percentage of plant N derived from fertilizer (PNDF) and the percent of fertilizer N recovered (PFNR) by the crop were significantly higher for the conventionally urea banded treatments 30 days after emergence. At harvest 4, 76 days after emergence significantly greater PNDF and PFNR were found in plants harvested in the nitrification inhibitor treatments as compared to the banded urea and large urea pellet treatments. This information suggests that the low amounts of NO_3-N found early in the inhibitor treated fertilized plots is correlated to the low amounts of N uptake also found in those plots early in the season. A greater accumulation of

N found in the inhibitor treated plots late in the season follows the higher amounts of NO_3-N found later in the Inhibitor treated plots. These data demonstrate the importance of timing the release of inorganic N (particularly NO_3-N) by the inhibitor treated fertilizer to the period of maximum crop N uptake.

Data collected in 1991 are still being analyzed but show similar relationships with respect to N uptake and nitrification inhibition. In 1991 we measured an 8 bushel increase in plots fertilized with the large urea tablets as compared with plots fertilized with conventionally banded urea, and/or inhibitor treated fertilized plots. In 1991 fertilization was done later at V3 verses V1 in 1990. It is possible that the V3 stage was just late enough to reduce inorganic N levels in the inhibitor treated soils to have missed the maximum N uptake period of the crop. whereas the larger tablets may have dissolved, hydrolysed and nitrified just slow enough to have resulted in greater amounts of inorganic N as compared to the other treatments during the high N demand period of the crop.

INTERPRETATION:

The DCD which was intimately incorporated with the urea maintained fertilizer ammonium N in the ammonium form for a longer period of time than CaC_2. The CaC_2 was not as intimately mixed with the urea as the DCD and only placed with the urea in the fertilized Zone. The greater encapsulation found with the DCD may partially explain the increased time of effectiveness measured with the DCD plots. Preliminary experiments in the laboratory with the wax coated CaC_2, indicated that we could expect a total conversion of the CaC_2, to acetylene (acetylene is the actual active agent that inhibits the conversion of ammonium to nitrate) in about 10 days. It is possible that a formation of acetylene gas (acetylene forms when CaC_2 combines with H_2O vapor in the soil atmosphere).

Since we haven't yet analyzed all of the data we can't indicate which combination of fertilizer and inhibitor is better at improving fertilizer use efficiency. It is possible that the DCD treatments inhibit the conversion of ammonium to nitrate for longer than required for maximum fertilizer uptake. From the literature we know that rapidly growing corn plants that are past the seedling stage prefer nitrate-N over ammonium-N. We also know that high concentrations of ammonium are toxic to plant roots. It is possible that the degree of delay in the conversion of ammonium to nitrate with DCD may be too long and may actually decrease the total fertilizer N recovered.

FUTURE PLANS: The experiment will be continued for a third season (1992) with basically the same measurements taken as in 1991. At the end of the 1992 season we will decide if any additional data is needed. We hope to have all of the ^{15}N-labeled plant material and soil inorganic N data analyzed for the 1991 season by the end of March of 1992.

THE OVERWINTERING BIOLOGY OF *DIURAPHIS NOXIA* ON THE NORTHEASTERN PLAINS OF COLORADO

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PROBLEM: The overwintering biology of the Russian wheat Aphid (*Diuraphis noxia*) Mordvilko has been researched in the field, and in the laboratory starting with the winter of 1988 and continuing to the winter of 1991. The major scope of the research was to determine what type of environmental conditions are necessary to cause 100% mortality in an overwintering population of Russian wheat aphids infesting winter wheat.

APPROACH:

FIELD STUDIES: The field studies involved artificially infesting var. Tam 107 plants in mid October and periodically sampling them through the winter. Sampling involved removing .3 m linear drill row of wheat plants that had been infested with 30 nymphal RWA for the winters of 1989, 1990, and 1991. Environmental parameters measured were soil surface temperature, (24 hr. averages for every day starting in October and continuing until the first of April), soil moisture, snowfall depth, number of days with snowcover, and fresh and dry weights of plants from infested .3 m sections. The data were analyzed using the Statistical Analysis Systems (SAS Institute 1982) max r option with RWA numbers as the dependent variable and the environmental factors as independent variables. An accumulative freeze index was developed to determine the effect of long term exposure to sub zero temperatures. The RWA numbers were regressed against the accumulative freeze hours.

LABORATORY STUDIES: Supercooling points (the instant of ice nucleation) were determined for 1st instar through adult life stages, and for both growth chamber (room temperature) and outdoor (acclimated) RWA. Aphids were attached to a copper constant 30 gauge thermocouple by a thin film of petroleum jelly, then slowly lowered inside a test tube that was submerged in a dry ice, alcohol bath. The rate of cooling was 1-2^0 C per minute. The lowest point on the temperature curve was recorded as the supercooling point. The search for cryoprotectants began by looking for glycerol levels in the RWA. An enzymatic test kit from Boeringer Mannheim was used with a spectrophotometer to establish a standard curve for glycerol. After 21 assays from both field and growth chamber RWA were conducted and no glycerol was detected, gas chromotograpy was used to again look for a broader range of oligosaccharides. This method of assay was used to look for sorbitol, glucose, sucrose, D-manitol and glycerol.

FINDINGS:

FIELD STUDIES: The RWA numbers from the .3m linear row foot samples (dependent variable) regressed against accumulated freeze hours resulted in high r^2 values and appears to be a good predictor of RWA decline. The second most important environmental variable measured was snowcover depth. Snowcover stabilizes soil surface temperature and provides a source of protection for the RWA during extremely cold periods. However, extended periods of snowcover are detrimental to the RWA. Soil moisture did very little to help improve the model. The data for wheat plant fresh and dry weights are still being analyzed.

LABORATORY STUDIES: There were no differences in supercooling points for field collected versus growth chamber reared RWA on a seasonal basis. There appeared to be a size relationship in that smaller

instar resulted in slightly lower supercooling points compared to larger instar and adults. This is probably due to smaller surface area on smaller aphids compared with larger instar. The mean supercooling point for all life stages was -26.9^0 C. This data coincides with that of Butts (1989).

Glycerol was not detected by spectrophotometry in RWA reared in a growth chamber or acclimated from as low as 3 ug/100ul of sample. This includes field aphids collected during the coldest period of the winter. The gas chromatograph analysis indicated that sorbitol, glucose, and sucrose levels were elevated in cold hardened RWA compared with non hardened aphids. D-manitol was one half the level in cold hardened aphids compared with non hardened. Glycerol again was not detected by gas chromatography. Further work for analyses of cryoprotectants in the RWA will be conducted.

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ROOT ZONE WATER AND CHEMICAL TRANSPORT AS ALTERED BY MACROPORES

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CRIS: 0500-00032-022

PROBLEM:

The work done by soil physicists over the last few decades has greatly enhanced our understanding of the water and chemical transport processes. However, not enough has been done to fully understand and quantify the effect of management practices. Yet, it is only through management practices that we can have some degree of control over these processes. Preferential flow paths and crop rooting patterns are, in a sense, a manifestation of certain management practices.

Major thrust of this work will be to develop basic understanding and theoretical framework for water and chemical transport processes in a field as influenced by soil conditions, such as macropores, and practices such as type of tillage, cropping, surface cover, chemical placement, and surface shaping. Special emphasis will be on the dynamics of a row-crop system of corn or soybeans, planted on lands of varying topography and soil profile characteristics. Effects of rooting systems on decayed root channels, earthworm activity, and spatial non-uniformity of water and chemical transport will be of great interest. The row-crop situations often involve 2-dimensional spatial changes as well as temporal changes in soil properties and surface conditions, and 2- or 3-dimensional water flow and chemical transport pathways. Basic knowledge and theory of processes under these conditions are very limited or essentially lacking at present. This information must be developed if we are to prevent ground and surface water pollution from agricultural chemicals, while maintaining and enhancing crop production.

Specific Objectives During 1991

Develop experimental understanding and a model to quantify the transfer of soil surface-applied chemicals to macropores and their downward transport through the root zone; study the effect of soil surface conditions and soil profile characteristics.

APPROACH: The role of macropore channels on water and chemical transport towards groundwater was studied in several experiments, using packed soil columns with and without artificial macropores, surface-applied tracer chemicals (Sr and Br), and simulated rainfall. The factors evaluated were: initial soil water content, surface cover, surface layer of large soil aggregates, soil layering, and the macropore made only in the top soil layer or only in the bottom soil layer versus a continuous macropore.

FINDINGS AND INTERPRETATIONS:

The transport of water through a macropore was much greater than that of a chemical. The transport was all transport was observed in a buried, subsoil macropore. The ARS Root Zone Water Quality Model was used to study the magnitude and characteristics of macropore flow for different soil and rainfall

conditions, of macropore sizes, and chemicals. Moderately adsorbed chemicals were the most susceptible to macropore transport. Macropore size had a small effect. A field method for determining macropore flow capacity and continuity was developed.

The results show that the continuity of macropores to the soil surface is critical to preferential flow. Thus, a shallow tillage to break this continuity will essentially prevent macropore transport. The application of chemicals when the topsoil is dry will reduce this transport too. Whereas surface soil aggregation increases macropore transport when macropores are open at the surface, aggregation retards downward movement of chemicals through the soil matrix.

FUTURE PLANS: The results will be used to evaluate the ARS Root Zone Water Quality Model, developed by our Unit, as well as some other models. Then models will also be used to quantify and interpret the extensive field data on the transport of nitrate and pesticides to surface and groundwater from MSEA sites in the midwest. Further experiments will be conducted in soil columns in which the plants are grown, to study the macropores generated by decaying roots, and their effect on preferential water and chemical movement.

CHARACTERIZATION AND MANAGEMENT OF SOIL WATER AND SOLUTES IN FIELD SOILS

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CRIS: 0500-00032-022

PROBLEM: The pollution of surface and ground waters can, to a large extent, be prevented by good management practices. However, the spatial and temporal variability in soil water properties of the field soils and the complexity of the processes involved, have to be characterized and understood well before suitable management practices can be devised and applied. This project aims at gaining a better understanding and quantitative characterization of the variability and processes at the field scale, and their interactions with management practices .

Specific Objectives for 1991

1. Model the behavior of fertilizers and pesticides in relation to chemigation.
2. Develop simpler methods for characterizing soil water properties of variable field soils.

APPROACH, FINDINGS, AND INTERPRETATIONS:

Objective 1

Modeling the behavior of fertilizers and pesticides in relation to chemigation: Integrated modeling of the soil-water-chemicals-plant-atmosphere system, in conjunction with some careful experiments, is the most efficient way to evaluate alternative management practices as to their effects on crop production and the environment. One such model recently developed by a team of USDA-ARS scientists, is called the Root Zone Water Quality Model (RZWQM). We demonstrated its utility in evaluating the effects of chemigation, as compared with conventional soil applications, on the retention and movement of fertilizer nitrogen and the herbicide atrazine in the root zone of a corn (maize) crop. Model simulations showed that when the irrigation water applications were tightly controlled so as to fill the depleted root zone to just field capacity, the split applications of nitrogen with 8 or 9 sprinkler irrigations only slightly retarded downward movement of the nitrate pulse through the root zone, as compared with either one initial soil application or two split soil applications. However, when the quantity of irrigation was increased to allow some leaching of salts, the retardation by chemigation increased. The overall movement, as well as retardation, were greater in a sandy loam soil than in a silt loam soil.

Objective 2

1. Evaluation of similar media scaling and a one-parameter model for estimating soil water characteristics: Two simple methods for estimating the soil water characteristic curve from saturated soil water content, or even just the soil bulk density, plus one other measured point on the curve (such as the 0.33 kPa water content) were evaluated. A similar media scaling approach and the one-parameter model of Gregson, Hector and McGowan were compared for eight diverse soils from within the U.S. The scaling method also requires knowledge of one complete curve to serve as a reference. The one-parameter model was extended to include the residual water content and the soils were divided into three

textural groups for the analysis. Visual comparison of the calculated versus measured soil water content for both methods showed less scatter in the relationship to the 1:1 line, concomitant with smaller calculated error terms, for the one-parameter model. These results demonstrate that the one-parameter model is better than similar media scaling in estimating soil water content.

2. Comparison of methods to estimate soil water characteristics from soil texture, bulk density, and limited data: Four approaches used to estimate the soil water characteristic (soil water content-matric potential relationship) were compared on a data set based on 366 cores of Bernow soil (Glossic Paleudalf). Regression equations based on soil texture and bulk density provided poorer estimates of soil water content, with large errors at some matric potentials, as compared with other approaches examined. A simple log-log interpolation/extrapolation approach, based on two measured values at -33 and -1500 kPa, provided results similar to the regression model with two known values. The similar-media scaling approach, utilizing one measured value at -33 kPa, displayed results similar to the log-log method, but the error was slightly higher. Estimates with the one-parameter model of Gregson, Hector and McGowan (GHM), based on one known value (-33 kPa), were similar to the log-log interpolation/extrapolation. We conclude that the models which incorporated even one known value of soil water content-matric potential relationship were much better than those based on soil texture and bulk density alone. The simple log-log interpolation/extrapolation and the one-parameter GHM model provided the best estimates of soil water content. The scaling method estimates were only slightly worse than the GHM model estimates. The soil survey data often contain at least one value of the water characteristic. These one-point methods should, therefore, be the methods of choice.

3. A comparison of three field methods to characterize macropore flow capacity. Most methods currently in use to characterize macropore flow capacity have serious limitations. In most cases only surface horizon or the top of an excavated horizon can be characterized or the soil is treated as homogeneous. Where soil is excavated, further field experimentation after the soil is characterized is impossible. In any case, characterization of the continuity of macropores in the profile is not possible when measurements are made on individual horizons. Furthermore, these methods sample only a small surface area, 7.5 to 20 cm in diameter. This area is unlikely to meet the criterion of a minimum representative sample volume for a macropores soil.

Motivation of this study was to examine a field method to characterize macropore flow capacity of the profile that removes or minimizes the above limitations. Such a method should also be a part of a general method that includes characterization of the unsaturated hydraulic properties of a layered soil matrix as well. We felt that these objectives could be achieved by the recommended field techniques of determining field-saturated and unsaturated hydraulic conductivities of the soil profile from tensiometric measurements during ponded infiltration and the following redistribution phase. The hydraulic conductivity at 30 to 40 mm suction can be obtained from the redistribution data, whereas the combined field-saturated hydraulic conductivity of the macropores and soil matrix is obtained from measurements during infiltration. The difference of the two values gives the contribution of macropores. In this report, we present a field comparison of this method with two other suggested methods of measuring macropore flow, (a) a thin land-cement crust technique, and (b) the increasingly popular tension infiltrometer. Agreement between the tension infiltrometer and the other two methods was quite good given the scale of the measurements, differences in instruments, and normal heterogeneities. Based on these results, redistribution data along with ponded infiltration rates can be used to determine macropore flow capacity. This flow capacity reflects the effect of continuous macropores and it can be determined for subsurface layers without soil disturbance. Furthermore, the K-ψ relationship of the soil matrix derived from redistribution data are necessary input for water and solute transport models.

FUTURE PLANS: We plan to study the variability and interrelationship of soil properties and plant growth parameters along a sloping, catena, landscape on the CPER station, Pawnee. Measurements will be made at 5-m grid on north and south facing slopes, at about 100 points each. Some soil properties will be determined on undisturbed cores taken at these points. A new scaling technique developed by us recently will be used in conjunction with trend and geostatistical analyses, to quantify the variability and interrelations. This pilot study will be extended later to the entire Great Plains.

WATER, NITROGEN, AND PEST MANAGEMENT MODEL TO PROTECT GROUNDWATER QUALITY

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Great Plains Systems Research Unit

CRIS: 0500-00032-022

PROBLEM:

Objectives: Evaluate, test, validate, and support the Nitrate Leaching and Economic Analysis Package (NLEAP) model and incorporate a geographical information system (GIS) into NLEAP, and develop new production management systems that include advanced irrigation systems and scheduling methods, nitrogen recommendations, scheduling, and application methods, soil water monitoring techniques, and pest management.

FINDINGS: Work progressed on the validation of the NLEAP model under irrigated agriculture in Colorado. A cooperative study with the Northern Colorado Water Conservancy District is providing soil and groundwater nitrate-N data suitable for model validation. Soil, land use, crop management, and aquifer data from the District are being assembled in GRASS GIS format for use with the NLEAP model. An NLEAP-GIS application is in progress to identify nitrate-N leaching hot-spots and suggest alternative management strategies across the District. Preliminary results suggest that the NLEAP model is a suitable tool for identification of nitrate-N leaching problem areas.

Preliminary planning work was started to develop a user-oriented model capable of scheduling both water and nitrogen applications to irrigated fields. The work will extend the ARS and Michigan irrigation scheduling models and incorporate portions of the NLEAP model. (In cooperation with Bruce Wylie, Colorado SCS, NCWCD staff, D.F. Heermann, and MSU scientists).

FUTURE PLANS: Our on-going cooperative research with the Northern Colorado Water Conservancy District will be continued and expanded (pending additional funding). We would like to extend our coverage to the entire District as opposed only to areas located around existing study sites. We intend to map nitrate leaching hot-spots across the District, and help identify best management practices to control nitrate leaching. Model development work will continue on the joint irrigation and nitrogen scheduling model. (In cooperation with Bruce Wylie, CSU scientists, Colorado SCS, NCWCD staff, D.F. Heermann, and MSU scientists).

ROOT ZONE WATER QUALITY MODEL

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CRIS: 5402-13660-002

PROBLEM: It is generally agreed that agricultural activity can be a major contributor to surface and groundwater pollution in rural areas. Recent research has shown that agricultural management of land use and tillage systems can have a very significant impact on hydrologic and chemical response. One way the effects of different agricultural management schemes can be analyzed is by detailed process modeling. Several models now receive regular use for such purposes, but they all exhibit their own peculiar technical weaknesses. Institutional factors and computer code characteristics essentially rule out the substantial modifications and improvements that would be required to bring existing models up to date. Therefore, the objective of the Root Zone Water Quality Model (RZWQM) project is to develop a scientifically sound model with full supporting data bases, expert systems, and documentation. This will use the most up-to-date methods available and be easily applied by users down to the local level. Strong emphasis has been placed on user-oriented features as well as technical capabilities because these features are as important to the researcher who may use the model as they are to SCS type users.

APPROACH: In order to avoid the problems of previous modeling efforts, a structured system analysis and design approach was taken in RZWQM development. This helped to insure a well-organized, well-documented model that is easy to maintain and modify as the situation may warrant. RZWQM is a comprehensive physically-based model intended to serve as a management tool for ranking alternative agricultural management schemes. The major simplification in the model is that it is spatially limited to a representative point on a field (one dimensional). There are six major components in the model: Physical Processes (includes hydrology and soil heat flux), Management, Crop Growth, Nutrients, Pesticides, and Soil Chemistry. The complete system is driven by Physical Processes, while some control is exerted by Management. The simulation core to the model is complemented by user interfaces for input and output. The input interface consists of a professional-quality screen-oriented input manager developed for user ease. The interface is built around menu-driven entry screens with extensive facilities for on-line help and determination of default data/parameter values. It is expected that this interface will significantly enhance model utility by both researchers and other users. The output interface provides publication quality graphics and tabular output, so model results can be better interpreted.

RESULTS AND INTERPRETATIONS: In previous reports we have discussed our approach to the development effort and status of various components. This is an update to those comments. The 1/0 programs are considerably improved, however they need the results of extensive use to be completely free of problems. Of particular interest is the fact that 2 and 3 dimensional plots of model output are automatically generated. These have been extremely helpful in testing and validating subsystem components. A new feature of the output is the generation 2 and 3 dimensional difference plots that can be used to study the difference in response created by two alternatives. During the year the crop model was extensively tested and the corn model performs quite well. We also interfaced a potato model. Less well tested are capability of handling soybeans, wheat, and a cover crop. The soil chemistry and nutrient components have been thoroughly reviewed and some minor changes made. They seem to be stable and mass balance is maintained. The pesticide model is in review at the present time and several changes have been made in the past few weeks. A new ET subroutine has been developed. It has been partially

tested and will receive more thorough testing in the near future before being added. There have also been a few changes in the characterization of hydraulic properties and the management component has been expanded to handle a greater variety of options. A first draft of the users manual and technical documentation have also been prepared.

FUTURE PLANS: In the year ahead the model will receive extensive testing as a complete system. This will be accomplished by working directly with the Mgmt. Sgst. Eval. Areas (MSEA's) of the Presidents Water Quality initiative. Extensive data bases are being collected that will help in model validation. The model will also help the MSEA's explain and evaluate their data and extrapolate results to other or more general assessments. We also plan to continue working with several other groups that are now using the model and have briefing sessions for SCS, Colo. State Univ. and other groups.

TWO-DIMENSIONAL CHARACTERIZATION OF TRANSPORT IN VARIABLY-SATURATED SOILS

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CRIS: 5402-13660-002

PROBLEM: This project is aimed at developing and field testing two-dimensional computer models of soil-water, heat and chemical transport in the unsaturated zone. They are needed to evaluate the impact of agricultural practices, and spatial variability of soil properties and surface conditions on the pathways of those constituents. Two-dimensional models require processing massive amounts of distributed data. Thus, a concomitant need is the availability of better techniques to readily create, manage and display large data files. Consequently, the major goals of this project are (a) development of a graphical user interface (2DSHELL) to process multi-dimensional input/output data, and (b) development of operational finite-element models designed to evaluate land management practices in situations ranging from row-crop plots to hillslope scales.

APPROACH:

(a) The 2DSHELL's pre-processor is designed to let the user set up a finite element simulation on the screen using a pointing device, keyboard and screen menus. An extensive screen menu system acts as the gateway to a multitude of model set up and execution options. Options the user can select directly from the screen include: automatic grid generation and optimization, selective zooming options, user-controlled scaling, specification of initial conditions and steady or unsteady boundary conditions, changing soil properties, computing constituent movement, etc. The finite element grid is generated automatically on the screen, with a minimum of input, and it serves as a base for the allocation of soil-water properties, initial and boundary conditions, and other distributed features using the pointing device. Distributed material properties are entered automatically via a relational database of soil properties and soil-water relationships. The 2DSHELL-model interface organizes the data entered in the pre-processor into a file readable by the finite-element model. It also utilizes screen menus to allow the user to enter model specific data. The 2DSHELL's post-processor enables the user to generate comprehensive output that includes graphic display of computed values in the form of time series, two- and three-dimensional plots, hard copies of tables and plots, and an interface to output-report generators via archiving files.

(b) An existing two-dimensional model, SOILSIM, is the kernel of this modeling effort. SOILSIM is a finite element model which simulates soil moisture movement and solute transport in variably-saturated porous media using Galerkin-type approximations. The research plan calls for evaluating and expanding this model to ensure its accurate representation of irregular soil domains, boundary conditions at the soil-air interface, soil structure, abrupt changes and irregular distributions of medium properties associated with soil horizons, thin plow pans, soil crusting, etc. The plan also includes extending SOILSIM's capabilities to accommodate hybrid computational grids, faster matrix solvers, two-dimensional root uptake models being developed by ARS colleagues, and reflect the effect of hysteresis of moisture movement and soil temperature. This model will be eventually linked up with a weather generator and a surface runoff-erosion model to properly characterize processes at the hillslope scale.

FINDINGS:

(a) A first version of 2DSHELL's pre-processor including automatic grid generation, bandwidth optimization, a soil-properties relational library, and two-dimensional graphical displays was completed and documented. Work continues on the development of the 2DSHELL-model interface and the post-processor. The later component is being done in cooperation with the RZWQM team.

(b) Considerable effort went into developing familiarity with the SOILSIM code, revising the program to improve its structure and documentation, examining its accuracy, and developing software needed to interface SOILSIM with 2DSHELL. Trial runs of the restructured finite-element code have been carried out with satisfactory numerical results.

INTERPRETATION: The ultimate aim is development of tools to use in evaluating agricultural practices, although the present project is strictly in the line of research. 2DSHELL is turning out into the powerful GUI that we envisioned. At this point the weakest aspects of SOILSIM are its inability to work with hybrid grids, irregular soil domains, its limited computational speed, and the lack of a heat transport component.

FUTURE PLANS:

(a) A complete, fully documented version of 2DSHELL will be in place by this FY end barring unforeseen difficulties; (b) work on the SOILSIM model during this FY will include handling hybrid computational grids, replacing the current matrix solver with a faster one, and adding a heat transport component.

RAINSTORM CHARACTERIZATION

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CRIS: 5402-13660-002

PROBLEM:

An important aspect of rainfall research is the problem of probabilistic characterization of rainfall for various applications. One such application is the study of seedling establishment (cooperating with G. Frasier of the ARS Rangeland group). A second problem is the study of climate change and its potential effect on agriculture. It is impossible to predict the results of changed climate until we accurately characterize the unchanged climate.

A second aspect of rainfall research is the need for a storm-generating model, similar to the daily-rainfall generating work of C. Richardson. Several computer simulation models designed to assess the effects of alternative management practices require short-time (breakpoint) rainfall data as driving input. Examples of such models include RZWQM, Opus, KINEROS, and CREAMS (Option 2). Available data sets are sparse and unwieldy. A storm-generating model is needed to supply users with required input data.

APPROACH:

The approach is to first apply basic statistical methods to characterize rainstorms. I will then employ more sophisticated mathematical approaches, including time series analysis and other stochastic methods, to sufficiently characterize and model precipitation.

The unique ARS Research Watershed data are applicable to the problem. Rainfall records from various U.S. climates provide information necessary to characterize and eventually model the occurrence and intensity patterns of rainstorms. There is also a wealth of daily rainfall data available from thousands of National Weather Service stations, with some records over 100 years long.

FINDINGS:

Initial statistical analyses have been conducted employing rainfall records from Fennimore, WI; Coshocton, OH; Watkinsville, GA; Riesel, TX; Boise, ID; Albuquerque, NM; and Tombstone, AZ. External storm features studied include duration, maximum intensity, total rainfall, time between storms, and time from storm start to peak. In addition to basic statistics describing storm population and central tendency, several distribution statistics were studied, preparatory to model development.

Several significant discoveries have resulted from the initial stages of this project, including possible relationships among variables (useful later in model development), and the important effects of data-recording scale on perceived storm characteristics.

The cooperative work studying the potential of grass seedling establishment began in 1991. Previous literature was reviewed, and possible future methodology was designed. Data from related areas were collected, and initial analysis was begun.

DEVELOPMENT OF AN IMPROVED INFILTRATION EQUATION FOR SURFACE IRRIGATION

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CRIS: 5402-13660-002

PROBLEM: Develop time-explicit infiltration functions for use in border irrigation simulation which use physically-based infiltration parameters.

APPROACH: Analyze and modify Kostiakov infiltration equations and compare modified version with available data.

FINDINGS AND INTERPRETATIONS: Empirical Kostiakov equations can be replaced with the developed physically-based relationships with little or no loss inaccuracy. The equations developed in this study can replace the Kostiakov type relationships in surface irrigation studies and help unify infiltration parameter databases.

FUTURE PLANS: A paper reporting this study has been accepted for publication in the first 1992 issue of the ASCE Journal of Irrigation and Drainage Engineering. No further work is planned because of the resignation of the principle investigator.

SEDIMENT INTRUSION AND DISSOLVED OXYGEN TRANSPORT IN THE SFSR SPAWNING AREAS

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CRIS: 5402-13610-003

PROBLEM: The USDA Forest Service, Intermountain Research Station (INT) at Boise, Idaho, is conducting research to quantify the effects of eroded sediments generated by timber harvest, road construction, storm events and wildfire on spawning areas and fishery resources of the South Fork of the Salmon River (SFSR). One important phase of this study requires accurate evaluation of the direct link between sediment deposition in salmon and steelhead spawning areas and fish survival and emergence. ARS has developed the only available sediment intrusion and dissolved-oxygen transport model (SIDO) that provides a means to help make this link. This prompted INT, as a part of the overall SFSR project, to enter into a cooperative research program with ARS to adapt the SIDO model to the conditions found in central Idaho.

APPROACH: A major objective is to extend the modeling approach used in the SIDO model to conditions prevalent in the SFSR. The plan of work also calls for coupling the U.S. Army Corps of Engineers' HEC-6 sediment routing model and the U.S. Fish and Wildlife Service Instream Water Temperature model (IWTM) with the SIDO model to fit conditions in the Poverty spawning area. Because fundamentally different mechanisms of sediment intrusion are possible in the SFSR, the present project involves investigating these mechanisms and revising the intrusion component of SIDO. We also assisted INT in the design of the field data collection program in the Poverty area. This field data will be used to verify and validate the models.

FINDINGS: Modifications to the SIDO model and its coupling with the HEC-6 and IWTM codes are completed. Field testing of the modeling package as a whole has been pursued concurrently and will continue for the remainder of the project duration. HEC-6 runs accurately reproduced water stage profiles measured in the Poverty area. Bed degradation simulations compared closely to a laboratory flume experiment. The bed armoring algorithms in HEC-6 did not satisfactorily simulate bed armoring compared to data from a flume study, but yielded reasonable characterizations of bed armoring in the San Luis Valley Canal, Colorado. The sensitivity of the IWTM to selected meteorological variables showed the relative importance of air temperature data in model predictions of instream water temperature. Comparisons of SIDO computations with field data from the Poverty area showed that the mean sediment intrusion mass can be accurately represented through adjusting a single calibration variable. This variable has physical significance and has relatively low model sensitivity. In addition, the model provided a reasonable estimate of the spatial variability shown by the field data.

INTERPRETATION: The assumptions underlying the HEC-6, IWTM, and SIDO models appear to be justified for the stated purposes. That is, the tests conducted so far indicate that using these models in a coupled mode is suitable for determining the impact of sediment intrusion on the SFSR spawning grounds.

FUTURE PLANS: Testing and documentation of model package and technology transfer to sponsoring Agency will be completed soon.

RANGELAND HYDROLOGY PROGRAM

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Great Plains Systems Research Unit

CRIS: 5402-13610-003

PROBLEM:

Optimal utilization of native rangeland will be increasingly important in years ahead as increased demands are placed on it for food and fibre production. Research in the past few years has shown that cattle, if left free to graze, will tend to concentrate in certain areas for feeding and for resting. Generally, they will select the most palatable grass to eat first, then move on to less desirable grasses. They will also tend to bed down in taller more lush grassed areas. Research has shown that this pattern of grazing is not the most efficient from the standpoint of regrowth; certain species will come back much faster after being grazed than others. Thus efforts are being made to find the optimal grazing pattern for some native rangelands.

At the Central Plains Experimental Range (CPER) located within the Pawnee National Grasslands northeast of Nunn, Colorado rangeland research has been going on for many years. This was also the site for the Shortgrass Steppe Biome Research Project of the 1960's. Thus a tremendous wealth of information exists in the area. In the last few years the National Science Foundation funded the Long Term Ecological Research (LTER) Program as a follow-up to the Biome Studies. The purpose of the LTER is to provide a long term base of research data to support additional research that would lead to a better understanding of the optimal use of these lands.

The LTER program in the CPER needs basic data on the hydrology of the area as part of the project. This particular area of the rangeland shows much diversity in a relatively small space domain. Different plant communities can be found throughout the area, but they do not seem to be found in the same place on the hillslopes. However, it is felt that one particular plant community is found where the soil-water complex is of a certain configuration. The Great Plains Systems Research Unit (GPSR) was approached to work cooperatively in the LTER to provide the hydrologic expertise. The objective of our participation was to study the movement and distribution of water and erosion in the area.

The Great Plains Systems Research Unit participation in the LTER will also enable us to test some of our model development work on a grassland ecosystem. We plan to use the Opus, RZWQM and the Smith/Hebbert Hillslope models to guide data collection and research on the CPER. These models have not been evaluated extensively in a grassland environment, thus this will give us an opportunity to test them in an environment that is rather extensive and could be a major application area. We would also like to test the Hillslope model which was designed for use in an area of continually changing soil characteristics.

APPROACH:

Since the LTER is a long term research program, hydrologic measurements are to be taken for a long period of record. Therefore, our recommendation is to collect two types of information at the site. One is data from rainfall simulator runs and the other is from natural runoff plots. Rainfall simulator runs are suggested for two reasons (1) natural events are relatively few in number because the area experiences

only 11-12 inches of precipitation annually; events of 1 1/2 to 2 inches are infrequent and runoff events may not occur every year. One to three runoff producing events per year is normal. However, this does not preclude studying soil moisture variation on natural plots throughout the year as they respond to small precipitation events. The second reason for using a rainfall simulator is to isolate the hydrologic response of individual soil-plant communities.

In the study area of the central plains, wind and geologic features have tended to cause obvious differences between north and east or south and west exposures on hills. The down wind hillsides generally have deeper and lighter soil, thus different environmental conditions. Our approach is to set up two series of experiments in the area. Each set consists of four natural runoff plots. Each of the plots starts at the top of the hill, but the length of the plots vary. The shortest plot extends only to the break in the hill and the longest plot will extend well down into the foot of the slope. The other two plots are intermediate in length. The bottom end of each plot is located as closely as possible to a place where there is a change in the soil characteristics.

Data are being collected to enable us to validate the models and show the downstream trends in soil moisture content, runoff rate, erosion, evapotranspiration and water quality characteristics. Rainfall, surface runoff, soil moisture content at several depths and locations, sediment concentrations, air and several depths of soil temperature, wind speed and direction, solar energy, long wave radiation from the soil-plant surface, evaporation from a class A pan, snow water content and wind erosion data will be collected from three locations at the site. Most of the meteorological data are being collected at a meteorological site by recording it on a Campbell 21-X recorder. The runoff rates are being measured with H and HS flumes equipped with floats and potentiometers to measure the flow depth. Flow depth, soil moisture, soil temperature, and wind data are collected from the four plots on each side of the hill and recorded on Campbell 21 and CR-5 recorders. Thus data from eight natural runoff plots will be collected. Four of these sites can be equipped with runoff samplers for sediment concentrations and water quality. Extensive measurements of the various plant communities will be required.

The plots are located far enough apart to enable placement of rainfall simulator plots between them. The rainfall simulator data will be nearly the same as that from the natural plots. They will enable us to get information on the individual soil-plant communities and define model parameters. The natural plots will then be used to validate model performance.

FINDINGS:

Since installation of the plots in the fall of 1986, there have been only a few runoff events; none in 1989 and only minor events in 1990 and 1991. The two most significant events occurred in August 1987 and August 1988, producing about 8.6 cm in 1.5 hrs. and 4 cm in 8 hrs., respectively. Intensities in the first storm reached 19 cm/hr and produced from 1 to 4.3 cm of runoff. Mean runoff from the northern set of plots was 3.8 cm which was 78 percent greater than those on the south that averaged 2.1 cm. Infiltration on the toe slope positions is much greater as indicated by much lower relative runoff rates from the longer watersheds. This indicates infiltration of runoff from upstream reaches. Upper and lower slope positions differed by up to 5 cm in infiltrated water. This is a very significant difference in areas that receive only about 30 cm of rainfall annually. Intensities in the second storm approached 10 cm/hr. and runoff was only 0.2 to 0.8 cm. Mean runoff on the north slope, 0.7 cm, was again greater than on the south slope, 0.5 cm. Differences in volumes of infiltration were much less than in the larger storm, but the pattern was consistent.

In 1989 the rainfall simulator was used on five simulator plots, two on the south slope and three on the north slope. Both upper and lower slope positions on both sides of the hill were subjected to simulation. Both wet and dry runs were carried out on each site. Results of the simulations are not yet available, because ponding corrections need to be made.

During the year, records of rainfall and runoff depths taken over the last 4 1/2 years have been processed using a data processing system. All charts from rainfall simulator studies have been digitized and entered in the computer; most natural events have also been processed thus far. During the summer of 1990 extensive bulk density, and textural analysis sampling was done on site for background soils information and transforming gravimetric to volumetric moisture contents in conjunction with the TDR work. In addition, TDR rods were placed in close proximity to neutron tubes so that simultaneous readings were obtained along with gravimetric samples. This permits us to develop soil moisture curves that are applicable both to neutron, and TDR readings. Gravimetric soil moisture samples have been processed, and results are computerized and tabulated. Soil moisture profiles have been plotted and TDR data have been computerized. Funding constraints in FY 91 prevented all but routine maintenance of instrumentation.

INTERPRETATION:

Limited data collected thus far support the following interpretations:

1. Substantial differences in infiltration capacity and tendency to generate runoff or accumulate runon exist over short distances within hillslopes and among hillslopes.

2. Expression of these differences depends strongly on the intensity and quantity of rainfall in an event.

Future observations of natural and simulated runoff will:

1. Improve quantification of the relationships between runoff-runon and rainfall characteristics, soil properties, slope characteristics and antecedent moisture conditions.

2. Provide data for model calibration and validation.

3. Provide data and modeling capabilities that can be used to address the ecological role of short-distance runoff-runon phenomena in the shortgrass steppe.

FUTURE PLANS: A complete assessment of the value of the site for ongoing work will be made in FY 92. It is possible, because of a change in the structure of the GPSR unit and interest on the part of the Rangeland research unit, that objectives of research at the site may be changed. However it is anticipated that more indepth sampling of the plant community structure and the spatial distribution of soil hydraulic and physical properties will be made. Soil samples for laboratory determination of the soil hydraulic characteristics will be collected.

OPUS MODEL AND APPLICATIONS

V.A. Ferreira
Great Plains Systems Research Unit

This project was conducted as a modeling team with Dr. R.E. Smith, ARS Irrigation and Drainage.

CRIS: 5402-13610-003

PROBLEM:

Numerous agricultural problems, including nonpoint-source pollution abatement and best management practice determination, can be approached with the application of computer simulation models. One such model under development is Opus, which originated as the CREAMS2 effort.

The climate change currently predicted by general circulation models will inevitably affect agriculture in the U.S. Our problem is two-fold. First we must predict the nature and severity of these effects, then we will provide guidance on management practices to optimize agricultural productivity and environmental quality under the new regime.

APPROACH: The Opus model was modified to simulate the GCM-predicted 4°C rise in average air temperature over a 50-yr period. Both the modified and unmodified models were then run for 50 years. The differences in hydrologic regimes predicted by the two scenarios are being analyzed and compared. Results of such tests will be more valuable than the currently popular "before-and-after" tests, which compare a hydrologic response period with the same period assuming a fixed temperature change. A literature search has been initiated to identify the global change state-of-the-art. I have also participated in several meetings and workshops aimed both at networking of individuals involved in global change research and at capitalizing on these studies.

FINDINGS: The model has been completed, tested, and documented. The Program User Manual is in the final stages of ARS publication. Results of a crop model validation/ parameterization study are being finalized. Findings include model sensitivity to crop variety as well as to climate, and sensitivity of the simple, lumped Curve Number runoff submodel to other program components, particularly the evapotranspiration and soil water models. Technology transfer efforts have included model use by graduate students at CSU, Florida State, and the University of New Mexico. Cooperators include R.E. Smith, F. Pons (CSU), R. Flynn (Auburn U.), E. McDonald (UNM), and W. Lauenroth (CSU).

FUTURE PLANS:

Future model development and support efforts will be with the Root Zone Water Quality Model under development by my new group. Some work may employ Opus, but only for applications for which RZWQM is currently unsuited (e.g., climate change and Curve Number applications).

Future plans also include the analysis of the modified-Opus study, and reporting the results.
I am chairing an American Society of Agricultural Engineers (ASAE) session (December, 1992) on hydrologic effects of predicted global change.

POTENTIAL OF WEATHER RADAR TO CHARACTERIZE TEMPORAL AND SPATIAL VARIABILITY OF THUNDERSTORMS

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Great Plains Systems Research Unit

CRIS: 5402-13610-003

PROBLEM: Investigate the potential of ground-based radar to provide detailed spatial and temporal information of thunderstorms.

APPROACH: Analyze the Colorado State University CSU-CHILL radar's ability to reproduce recording rain gauge, rainfall intensity measurements at the USDA-ARS Central Plains Experimental Range.

FINDINGS AND INTERPRETATIONS: Breakpoint rainfall records derived from the radar compared favorably with ground measurements at nine sites within or neat the CPER for an intense summer thunderstorm. The radar was able to give 2.5-minute time resolution and 1.0 kilometer space resolution with apparently good accuracy. The results indicate hat radar should be investigated as a tool in the development of breakpoint, stochastic rainfall generation models. The advent of the NEXRAD system will make radar data generally more available. This tool should be exploited in terrestrial, global change hydrology research.

FUTURE PLANS: A paper reporting this study will be given at the AWRA meeting in Reno, Nevada in November, 1992 and a manuscript will also be submitted to Water Resources Bulletin. No further research in this area will be undertaken because of the resignation of the principle investigator.

ANALYSIS OF GREAT PLAINS CROPPING SYSTEMS

C. Vernon Cole
Great Plains Systems Research Unit

This research is part of a team effort in an agroecosystem science program. Collaborators include ARS Scientists: Marv Shaffer, Greg McMaster, and Jon Hanson and Colorado State University staff through Specific Cooperative Agreements and a Research Support Agreement: Ingrid Burke, Edward Elliott, Klaus Flach, William Hunt, William Parton, Gary Peterson, and Dwayne Westfall.

CRIS: 5402-61660-003

PROBLEM: The semiarid North American Great Plains have been the site of a major disturbance over the past 100 years by conversion of large areas of grasslands to cultivated cropland. This conversion, which in other semiarid areas of the world has led to decertification and drastic losses in productivity, has taken a different direction in North America with the introduction of improved management practices involving minimum soil disturbance, maintenance of residue cover, and higher yielding crop varieties. Productivity of the region is substantially higher now than when sod was broken and shows signs of continued improvement. Soil organic matter levels and nutrient reserves which showed sharp declines in early years have stabilized and are improving under current management. Why are the trends observed in the Great Plains different than in other parts of the world? What mechanisms are responsible for these differences? Can semiarid agroecosystems of the Great Plains be managed for productive and sustainable agriculture given the variable nature of weather patterns and intensive land use?

APPROACH: We have developed an approach to agroecosystem analysis that integrates a complex array of information from laboratory, site, landscape, and regional scales (Elliott and Cole 1989). Process-level information is integrated and used to develop the agroecosystem model or modify existing models. The model is validated using information from regional site networks. Sets of driving variables generated from geographic information and organized with geographic information systems (GIS) are used as model input. Model output is assigned to corresponding sub-regions using GIS to obtain regional information (predictions). Gaps in our ability to explain regional patterns drives new research on processes.

FINDINGS:

Literature on historic changes in land use and estimates on CO_2 release to the atmosphere that can be attributed to these changes was reviewed and major research issues were identified. The literature on the effect of conservation tillage on soil organic matter content was reviewed and statistical evaluation of available data was completed.

A study of the relationships between wheat yields for the major wheat growing counties of Colorado for the years 1929 to 1989 was completed using a spreadsheet adaptation of Thornthwaite's water balance model. Corrected monthly temperature data were generated from NOAA records and relevant statistical analyses were performed. The model accounted well for differences in average yields between counties but annual predictions suffered from uncertainties whether precipitation events toward the end of the growing season influenced yields for the year in question.

Soils at all landscape positions in the joint ARS-CSU cropping systems experiments at Sterling, Stratton, and Walsh, Colorado were sampled. Complete characterization was arranged through the National Soil Survey Laboratory, SCS and results evaluated.

Literature on historic changes in land use and estimates on CO_2 release to the atmosphere that can be attributed to these changes was reviewed and major research issues were identified. The literature on the effect of conservation tillage on soil organic matter content was reviewed and statistical evaluation of available data was completed.

Organic matter fractions were physically separated from within the structure of aggregates isolated from cultivated and native grassland soils. No-till soil had more C and N associated with the macroaggregate structure than the other tillage treatments. Sonication of the macroaggregates revealed an organic matter fraction that contained 10-20% of the total soil C and 8-28% of the total soil N. The amount of C and N associated with this enriched labile fraction (ELF) increased as the intensity of cultivation was reduced. The specific rates of mineralization of the ELF fraction from the three tillage treatments were not different, but were greater than that for intact aggregates. The quality of the ELF organic matter was the same for all tillage treatments and the ELF fraction appears to be physically from decomposition within the structure of the soil. The specific mineralization rate of native sod ELF fraction was ten times higher than that for the tilled soils. This suggests the ELF fraction formed under tilled soil is different than that formed under grassland soil. Partitioning of the C and N into organic matter fractions differed in no-till soil when compared to native sod soil. In native grassland soil, 40% of the total soil C and 29% of the total N were associated with the particulate organic matter fraction, with a smaller percentage being stored in the ELF fraction. The opposite was true for no-till soil, where 28% of the total N was associated with the ELF fraction. However, the ELF fraction from no-till soil was not as labile as native sod ELF. This soil organic matter research suggests that no-till management ameliorates the degradative effects of cropping by improving aggregate stability and increasing C and N accumulation.

<u>Organic Matter Workshop</u>

A Synthesis Workshop: Advances in Soil Organic Matter Studies: Global Change Issues was conducted in September 1991 at Pingree Park. A series of twelve papers was presented dealing with recent developments in concepts and methodologies in studies of soil organic matter formation and turnover. The focus of these reviews was the relevance to issues of global change resulting from shifts in land use and management as well as potential climatic shifts. These papers are currently under review and will be submitted jointly to a peer reviewed journal with wide exposure to the scientific community. Authors include David Jenkinson (Rothamstead), Hans van Veen (Wageningen), Keith Paustian and Eldor Paul (Michigan State) Bill Parton and Ted Elliott (CSU-NREL), Phillip Sollins and Peter Homann (Oregon State), George Wagner (Univ. of Missouri), David Schimel (UCAR-CSMP), Susan Trombore (Lawrence Livermore Labs), Edward Gregorich (Ag Canada, Ottawa) and Vernon Cole (ARS).

Organic C, N, S, and P Formation and Loss From Great Plains Agroecosystems

This is the final year of this collaborative research project with Colorado State University (E.T. Elliott, C.V. Cole, W.H. Hunt, W.H. Parton, G.A. Peterson and D.G. Westfall) with major funding support from the National Science Foundation (BSR 8605191). Over fifty five publications have resulted from this interdisciplinary research effort from 1987 to the present.

This research has focussed on evaluation of large-scale and long-term impacts of past management and potential changes with new management practices and a changing climate. Process studies have been conducted at three long term crop management sites located across a PET gradient in eastern Colorado. Agroecosystem analysis has been extended to landscape and regional scales using large scale data bases. Regional data bases and ecosystem simulation models are being used to predict agroecosystem properties over large areas. Multiple layers of spatial information on soils, climate and management were incorporated into a geographic system to drive the ecosystem model. Regional simulations have been verified by comparison to remote sensing data layers. This project has led to the development of several spin-off projects relating to regional analysis of agroecosystems.

INTEGRATED SIMULATION MODELS OF SOIL-CROP-ENVIRONMENT-ECONOMICS SYSTEMS

Marvin J. Shaffer
Great Plains Systems Research Unit

CRIS: 5402-61660-003

PROBLEM: Given the current state of the national farm economy and the renewed concerns about groundwater pollution from nitrates and pesticides, there is an urgent need to find ways to optimize on-farm productions for profit and yet minimize adverse environmental impacts. Time is a critical factor in the overall problem, and we cannot afford 10 or 20 years of additional field research before optimal systems are identified. In addition, while existing data sets provide long and short term information at selected sites, they do not begin to cover the range of soil, climate, and management combinations which are encountered in the field. Farm and natural resource managers lack suitable tools which can provide answers now before additional damage is done to the farm economy and the nation's soil and groundwater resources.

Objectives:

To develop productive and sustainable management systems for semiarid croplands that maintain farm profitability and protect the environment.

Integrate soil, climate, and management inputs with basic physical, chemical, and biological mechanisms associated with semiarid croplands by developing and applying both comprehensive simulation models and specific user-oriented models of total soil-crop-environment-economic systems.

APPROACH: To help solve these problems, models suitable for development and analysis of total crop production systems are urgently needed for use in agriculture. These models should integrate (1) the biological, chemical, and physical factors, (2) cultivars and management practices, and (3) physiological responses of crops to their environment into simulations of total agricultural systems for determining the limits and sustainability of agricultural production in semiarid agroecosystems of the Great Plains and elsewhere in the United States and the World.

FINDINGS:

The national NLEAP model for identification of potential nitrate-N leaching hot spots was completed and published in 1991 along with the Upper Midwest soil-climate data base, two descriptive book chapters,and a book appendix. Farmers, action agencies, and consultants now have an improved tool for design of management strategies to reduce nitrate leaching from agriculture.

NLEAP climate data for all other regions of the country have been extracted from CD-ROM media and statistically analyzed for wet, average, and dry years of record. Statistics were compiled to complete the master list of climate stations and years that will be in the NLEAP climate database for Regions 2 through 4. Current work on the climate database includes continuing development of winter evaporation algorithms to complete monthly climate values and producing daily precipitation data for all stations. Database specialists have completed the preparation of soils data for NLEAP format and are in the process of testing soil databases in NLEAP for Regions 2-4.

Knowledge about the spatial occurrence of NO_3 leaching in agricultural systems is needed to manage nitrogen for productivity and groundwater quality. The Nitrate Leaching and Economic Analysis Package (NLEAP) model was linked the GRASS Geographic Information System (GIS) to evaluate the risk of NO_3 leaching to groundwater from cropland in the Sycamore Creek Watershed, Ingham County, Michigan. The spatial distribution of various NO_3 leaching indices were predicted using NLEAP for continuous corn under recommended nitrogen fertilizer management in combination with spatial data contained in the GIS. This analysis delineated potential NO_3 leaching hot spots within the Sycamore Creek Watershed. The linkage between NLEAP and GIS provides a new tool for use in targeting current water quality initiatives on a national level. With additional development and testing, the NLEAP-GIS technology shows promise in the development of farm plans to meet emerging water quality standards for the protection of groundwater resources under agricultural lands. (In cooperation with F.J. Pierce, R.F. Follett, and Bruce Wylie).

The NLEAP model is being used in a cooperative study to identify nitrate leaching hot spots under irrigated agriculture in the Northern Colorado Water Conservancy District. (In cooperation with Bruce Wylie and NCWCD staff).

A study was completed that used NC 174 regional research data and the NTRM simulation model to determine long-term effects of soil erosion on corn production across the Upper Midwest. Results indicated that long-term corn yields on 9 benchmark soils were reduced by an average of 11 percent on severely eroded versus control sites. (In cooperation T.C. Schumacher and other NC 174 regional research committee members).

We continued development and field data collection for the NTRM weed-crop interaction and intercropping submodel. The 1990 South farm field plots were continued in 1991. Bill Conklin, biological technician, was hired to assist with the field and laboratory analyses. Field results continued to show that competition for light, water, and nitrogen restrict the growth and dry matter potential of both amaranth and corn as compared with monoculture conditions. As water stress levels increase, the percentage of total biomass shifts downward for corn and upward for amaranth. The opposite effect is observed in the case of nitrogen deficiencies. Model development was essentially completed and testing was done using the field plot data for 1987-1990. Results indicated that the model could simulate crop-weed interaction data from the South farm plots, and sensitivity analyses showed that the model responded correctly to variable emergence dates for corn and pigweed, and to variable populations of the two species. Ed Schweizer is interested in using the model to supplement the data bases for his bioeconomic crop-weed modeling work. A manuscript was submitted to Agricultural Modeling. (In cooperation with E. Schweizer, and J. Radke, ARS National Soil Tilth Lab.).

The NTRM low-input systems study done in cooperation with the Rodale Research Center was completed. Results indicate that the NTRM model is capable of adequately simulating both conventional and low-input management systems with respect to corn and soybean yields, soil temperature, soil water content, and nitrate-N occurrence and movement at the Rodale Research Center farm. A journal manuscript dealing with corn grown in with both conventional and low-input management was published in Ecological Modeling. A second manuscript dealing with soybeans was prepared for submission in 1992. (In cooperation with J. Radke, Kim Kroll(Rodale), Dan Ball, and others).

The nutrient submodel component of the RZWQM model was refined to include greenhouse gases and tested against laboratory and field data. Documentation was prepared that described the theoretical basis of the nutrient and soil chemistry components of RZWQM. The submodels will be tested further in conjunction with the rest of RZWQM as applied to field scale research plots in Iowa, Colorado, and

elsewhere. Considerable interest in RZQWM is being shown locally by irrigation district, city, and consultant personnel concerned with movement of nutrients and other solutes. Additional model validation studies were continued in cooperation with A. Sharpley, ARS, Durant, OK. (In cooperation with Laj Ahuja, J. Hanson, D. DeCoursey, A. Sharpley, G.R. Dutt (Univ. of Arizona), K. Rojas, and C. Hebson).

A new project was continued to study the effects of drought on dryland agricultural production in the Great Plains. This is a joint effort involving myself, C.V. Cole, and J.D. Hanson along with our respective staffs. We assembled the climate data for long-term stations in the region and developed the kriging and GIS techniques needed to map and examine these data. We also reviewed the pertinent literature and assembled historical crop yield information. We determined that the soil water budget submodel developed for the NLEAP model could be used to quickly project drought indices (transpiration deficits) for the entire region.

FUTURE PLANS:

We intend to complete work on the remaining NLEAP database regions 2 through 4. The soils database for the entire country is nearly completed and is being tested, the remaining climate database analyses and user files should be ready by the end of FY '92.

We will be continuing our cooperative project to study the effects of drought on crop yields in the Great Plains. By the end of FY '92, we should have a general assessment of wheat yields over the region as a function of transpiration deficit (drought index) for each year in the long-term historical record (early 1900's to present). We will then use our GIS capabilities to decide which climate, soil, and management combinations to include in a more detailed management assessment involving the NTRM, Century, and other detailed models. (In cooperation with C.V. Cole, J.D. Hanson, K. Flach, and others.)

We will be revising and updating the NTRM technical and user guides previously published in 1987. Emphasis is being placed on the new capabilities in the area of low-input sustainable agricultural systems. Draft copies should be available by the end of the fiscal year, with publication sometime in 1993. (In cooperation with Dan Ball and J. Radke).

The nutrient and soil chemistry submodels currently in NTRM will be updated based on new information and code being developed in conjunction with the RZQWM project. We will submit journal articles for publication that describe the RZWQM nutrient and soil chemistry submodels (In cooperation with Laj Ahuja, D. DeCoursey and A. Sharpley).

In cooperation with A. Halvorson, the NLEAP, COFARM, and FLEXCROP models will be combined and expanded to produce a farm management model suitable for Great Plains agriculture. This model will have expert-system-like components, be linked to regional data bases, and allow site-specific management assessments to maximize economic returns to farmers and protect the environment. We are optimistic that the technology developed for the models mentioned above can be directly adapted for use in a more general farm management tool.

The NTRM model will be applied to data collected at the three crop production research sites in eastern Colorado in cooperation with G. Peterson and D. Westfall of the CSU Agronomy Department. The objective will be to test NTRM under these conditions and to make recommendations concerning future data collection at these and other sites.

EFFECT OF MANAGEMENT PRACTICES ON CROP DEVELOPMENT AND PHYSIOLOGY

Gregory S. McMaster
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CRIS: 5402-61660-003

PROBLEM: Developing sustainable cropping systems for the Great Plains requires selecting among many cultural practices that are directly affected by climate. Large variation in germplasm and soil reactions to different cropping systems exists, and there are numerous pathways to final yield and overall system response. The documented increase in atmospheric CO_2 and possible global climate complicates developing sustainable cropping systems.

APPROACH:

In the last decade, a great deal of research was conducted towards understanding the development and physiology of small-grain cereals and other crops for specific environmental variables. Very little is known about how management practices affect crop development and physiology. Since it is impossible to study all the different management practices for different soils, climates, and crops, a combination of experimentation and simulation modeling is being used to synthesize existing knowledge and fill knowledge gaps on crop responses to the environment and management. The approach is first to try to quantify the effects of management practices on the physical environment (e.g., soil temperature, soil water, soil nutrients). Then, integrate the existing knowledge of how the physical environment affects crop development and physiology, into detailed mechanistic models that simulate the processes. Experimentation is important in this approach to fill knowledge gaps.

This approach has several advantages. (1) Alternative management practices can be evaluated by determining their impact on the physical environment, and then using the simulation models to assess how the system will respond to the altered physical environment under different climates and soils. This significantly reduces the time and resources necessary to conduct extensive field studies for different management practices, soils, crops/cultivars, and climates. (2) The suggested responses inferred from the models can then be validated by selective field experiments, once again shortening the time and resources necessary to develop and evaluate different cropping systems. (3) Future management practices can be evaluated as they emerge using the approach outlined above. (4) The models can also be used to evaluate altered simulated physical environmental conditions. If certain alterations of the physical environment seem particularly advantageous, then this suggests areas that management practices should focus on to produce the desired affect. (5) If the models accurately simulate the responses to the physical environment, and if all the important developmental and physiological processes are simulated, then other issues such as global climate change impacts can be evaluated. It is important that all the potential developmental and physiological processes are simulated in order to have confidence in the predictions of the model, and most importantly, so that an understanding of why the system has responded as it did. Too often current simulation models have been used to assess global climate change where a number of important developmental and physiological processes have not been included in the model (or they have incorrectly been included), and no understanding of the system response has been gained.

FINDINGS AND INTERPRETATIONS:

Experiments and modeling to fill knowledge gaps on crop developmental and physiological responses to the environment and management practices have been completed or are in progress.

(A) A growth chamber experiment was completed that examined wheat developmental and physiological responses to elevated CO_2 concentrations. Certain key developmental events such as phenology, tiller appearance and survival, and spike development were significantly affected by CO_2. Importantly, wheat was found to photosynthetically acclimate to higher CO_2 levels. This lends increasing support to the contention that many models are erroneously assuming that higher CO_2 levels will result in higher net CER rates.

(B) The second year of data has been collected on wheat yield and yield component responses to different cropping systems and soils along an ET gradient with similar rainfall. The most important processes that are controlling yield are related to tiller appearance and survival, with spike differentiation processes second in importance.

(C) An experiment was started Fall 1991 to examine the effects of tillage and residue cover on wheat development and physiology. Companion studies are being conducted in Michigan and Ontario, Canada. No reportable results yet.

(D) An irrigation scheduling study was completed. Wheat developmental and physiological responses were evaluated, and irrigation at jointing was a critical time for final yield. Jointing is a key period for tiller survival, and tiller number is a/the key yield component often in the Great Plains.

(E) Two detailed mechanistic simulation models (SPIKEGRO and SHOOTGRO) of winter wheat development and growth were completed. The important result of these models is that the foundation is now present to integrate detailed developmental and physiological concepts.

(F) I have hypothesized that many, or most, of the developmental and physiological concepts incorporated into SPIKEGRO and SHOOTGRO should apply to other small-grain cereals, crop grasses, and rangeland grasses. To begin to test this hypothesis, SPIKEGRO and SHOOTGRO are being modified for spring wheat and spring barley. This work is in progress, yet the hypothesis appears to be valid.

FUTURE PLANS: Projects B, C, and F will be continued. Modifications of the winter wheat models (E) will continue. A similar experiment as C will be started for corn. Lastly, I will work with the plant submodel in the RZWQM model and incorporate the winter wheat, spring wheat, and spring barley models into the RZWQM model.

DEVELOPMENT OF A COMPREHENSIVE PLANT GROWTH SIMULATION MODEL

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CRIS: 5402-11660-001

PROBLEM: Our research involves the maximization of rangeland and cropland use while preserving the natural resource. In this vein, comprehensive plant growth simulation models are being developing. Components have been developed for two extensive simulation models: SPUR and RZWQM.

APPROACH: We are using a systems approach to solve questions describing rangeland dynamics. The solution of these questions will help:

Extend our capability and leadership in identifying land covers and the general health and vigor of plant growth.

Monitoring grasslands and evaluating the influence of human-induced environmental and climatic change.

Provide knowledge on the effect of potential climate changes on grassland and livestock production.

FINDINGS AND INTERPRETATIONS:

A comprehensive plant growth simulation model to predict was completed. The model is being used as the plant component for SPUR and RZWQM. The model is general enough to predict the relative response of various crops to changes in soil water and chemistry in conjunction with different management practices. Crops include herbaceous plants grown for fruit or forage. They can utilize either C3 or C4 metabolism and can be annual or perennial. Selected crops include, but are not limited to corn, pinto beans, soybean, cotton, wheat, and various grasses. Chemical applications were defined as any chemical added to the crop to increase growth rate or quality of the plant or to remove undesirable biological components from the system (such as insects or weeds). Management practices included other anthropogenic influences used to modify the environment or cropping sequence in order to improve the productivity of the desired crop, i.e. irrigation, time of seeding, cropping methodology, etc.

The SPUR model was also used to evaluate the ability of the model to predict spatial and temporal changes in rangeland productivity. The SPUR model was able to explain between 50 and 95 percent of the temporal variation in average sample estimates of green biomass for a majority of the pasture/soil sites simulated. However, the SPUR estimates were usually greater than the ground sample estimates. The detection of spatial relationships between SPUR and sample estimates of green biomass within sample periods was unsuccessful. Possible reasons why the model was unable to predict spatial changes in green biomass and produced biomass estimates greater than sample estimates included: improper parameter selection for the soils simulated, ineffective grazing distribution, the lack of spatial connectivity between the sites simulated, improper biomass and nutrient distribution within the various model components, and poor ground sample estimates of shrub production.

These findings suggest that SPUR simulation is able to predict general changes in green biomass over time for a single site. Our inability to accurately estimate all of the parameters required to simultaneously simulate multiple sites limits the model's ability to estimate changes in green biomass over space.

USE OF REMOTE SENSING WITH ECOLOGICAL MODELING

Jon D. Hanson
Great Plains Systems Research Unit

CRIS: 5402-11660-001

PROBLEM:

Remote sensing techniques can be used for estimating rate processes such as evapotranspiration and primary production. These techniques can also be used to index variables such as cover and green leaf area. The information provided by remote sensing techniques can be used to parameterize models and verify their predictions. The combination of spatial information and modeling will maximize the usefulness of both tools and facilitate extrapolation of simulation results to large areas such as farms, ranches, and entire regions. The ultimate goal is to develop and validate process-oriented models that can accept spatial information, along with necessary in situ data, as input. Specifically, remotely sensed data and simulation modeling can be combined in three ways. First, remote sensing data can be filtered with data generated from simulation models to produce predictions of biomass production and accumulation with the lowest possible variance. Second, values obtained from remote sensing imagery can be related to elements within the model so remotely-sensed data can subsequently be used as surrogate variables for the simulation model. And finally, correlations between satellite imagery and output from the simulation model can be determined so that simulation results from small areas can be extrapolated to entire regions.

The general objectives include:

> Development and validation of mechanistic, process-oriented models which can accept remotely sensed data, along with necessary in situ data, as input.
>
> Monitor and predict global changes in primary production, to evaluate the effect of these changes on hydrologic processes, and determine if the impacts on hydrologic processes can be monitored using remote sensing data. Specifically, the objectives are:

1. Determine the dependability of remotely sensed data and simulation results in measuring biomass production and accumulation.

2. Evaluate the relationship of AVHRR and LANDSAT derived spectral transformations and key variables simulated by an ecological model.

3. Demonstrate the utility of integrating remote sensing and modeling processes for area-wide monitoring of ecological processes.

APPROACH:

The SPUR model is being used extensively on rangeland in a present study involving Colorado State University (CSU), the Agricultural Research Service (ARS), and the EROS Data Center. Specifically, the SPUR model and remote sensing will be used in conjunction to expand our ability to simulate brushlands, woodlands, and irrigated farm lands on a stratify portion of eastern Colorado. To accomplish

this activity CSU, ARS, and EROS will work closely together. EROS Data Center is asked to provide AVHRR data and some LANDSAT data for selected study areas of Eastern Colorado. EROS will also work closely with ARS and CSU in relating the Normalized Difference Vegetation Index (NDVI) to crop production for rangeland, shrubland, rangeland, and crop land including corn and wheat. CSU will determine the relationship between land-use, satellite imagery, and simulation results. ARS will modify the SPUR simulation model so that the plant model includes a state variable for the woody portion of shrubs and is parameterized to simulate rangeland, brushland, woodland, corn, and winter wheat.

Correlations between land use, remote sensing, and the simulation model will help in the develop of strategies for regional monitoring of the Great Plains agricultural system. The appropriate spatial and temporal scales will be determined. When completed, this research will result in new and improved methods for evaluating regional and even global processes through the combined use of simulation models and remotely sensed data. With these tools, we will be able to monitor and predict large regions of vegetation in response to climatic and edaphic changes.

FINDINGS AND INTERPRETATIONS:

During this project (1989-present) we have acquired and registered 30 AVHRR scenes, seven LANDSAT thematic-mapper scenes, and two SPOT scenes. Also, for two periods of the 1990 growing season we acquired infrared video and color infrared and color photography. The video was taken at about 2285 m and the photography was taken at 1520 and 3050 m. These images are being included in our GIS data base for further analysis.

Strong relationships existed between sample estimates of dried green biomass and vegetation indices derived from LANDSAT Thematic Mapper data. Relationship detection, however, was dependent on the method used to combine the vegetation indices with the ground data. No strong relationships were found when single sample estimates of green biomass were combined with the average vegetation index response for a nine-pixel area. Sample point location errors and the inability of a single sample to characterize each nine-pixel area probably contributed to the lack of strong relationships.

A strong relationship was found between average sample estimates of dried green biomass and the average vegetation index values during the June 1990 sample period when the data were combined into spectral classes. However, the same level of association was not found for the August 1989 and September 1990 sample periods. The spectral classification procedure did not effectively use the available range of greenness information nor did it reduce the influence of soil background reflectance, perhaps due to the identification of too few classes.

Strong relationships were found for all three sample periods (Aug. 1989, June 1990, and Sept. 1990) when ground data and vegetation indices were averaged within greenness strata. Averaging the green biomass and vegetation index values within greenness strata reduced the number of ground samples required to characterize each class and the influence of bare soil reflection on the relationships. The percentage of association was highest for the August 1989 and September 1990 sample periods ($r^2=0.95$) and lowest for the June 1990 sample period ($r^2=0.71$). The reduced association between dried green biomass and the vegetation indices in June 1990 probably resulted from the 16-day separation between the sample period and image acquisition.

ECOSYSTEM FUNCTION AND STRUCTURE

Jon D. Hanson
Great Plains Systems Research Unit

CRIS: 5402-11660-001

PROBLEM: A delicate balance between water, temperature, and productivity exists in the semiarid rangeland. In these rangelands, the "ecological health" or sustainability of the system is largely determined by the activity occurring within the rooting zone. In the short term, decomposition of soil organic matter apparently enhances production. However, in the long term, soil organic matter depletion leads to a degradation of the ecosystem.

APPROACH:

Two studies have been initiated to evaluate the root zone dynamics of semiarid rangeland. The first project seeks to determine the relationship between net primary production, root zone dynamics, and grazing behavior. Specific objectives include:

> Compare the relative influence of different grazing management strategies on rangeland sustainability.
>
> Determine the interaction of seasonal weather dynamics and grazing system on rangeland sustainability.

The second project will investigate the temporal and spatial variance of soil and plant properties within a rangeland system. Spatial autocorrelation techniques will be used to investigate the spatial distribution of soil carbon, nitrogen, and particle size in relation to vegetation cover on a rangeland hill slope and a playa.

FINDINGS AND INTERPRETATIONS: This work has just begun.

FUTURE PLANS:

Future studies should combine SPUR simulation and LANDSAT imagery for regional green biomass assessment. The technique should incorporate the best attributes of both tools. The following approach is one method that could be used to combine the two tools. LANDSAT imagery should be acquired at key periods throughout the growing season. The LANDSAT data could then be used to stratify the region into greenness strata. Meteorological sites capable of providing historical climatic information necessary to drive SPUR must then be located and climatic data obtained. SPUR simulation sites should be placed in as many different greenness strata as exist around each meteorological site. Soils occurring at each simulation site must be identified and hydrology and soil parameters determined from soil data-base information or soil samples. Historical grazing information must also be acquired for simulation sites that are grazed by livestock. Model warm-up should be accomplished by running the model for at least 18 to 20 years prior to the study period using historical climatic data and grazing information. SPUR predictions of green biomass and the corresponding average vegetation index value within each strata should be used to develop a calibration curve which relates green biomass estimates

to vegetation index response. The calibration model and the average vegetation index values for each greenness strata could than be used to estimate green biomass amounts for all strata occurring within the region.

The success of SPUR simulation of green biomass production is dependent on proper parameterization of the model. The collection of soil samples, from which hydrology component parameters can be estimated, may improve the ability of the model to predict green biomass amounts at that location. Determining how best to initialize the model remains a problem. One approach to model initialization would be the collection of baseline information on the distribution of carbon and nitrogen in the various biotic and abiotic components of the ecosystem, however, it would be impractical to assume that enough information could be collected to characterize multiple sites. Running the model for 18 to 20 years prior to the study period appears to be necessary for model warm-up.

Our inability to adequately characterize the complex spatial interactions that affect biomass production and utilization suggest that SPUR should be run on an individual site within a grazing unit rather then attempting to simultaneously simulate multiple sites. Prediction errors will result from the lack of spatial connectivity, however, the errors will not be compounded by incorporating guesses of the sites preference and site limitation vectors for grazing distribution, as was the case in the current study.
Future studies designed to develop relationships between sample estimates of dried green biomass and LANDSAT derived vegetation indices should combine the data into areas of similar biological response. Strata can be developed by delineating various plant communities or by classifying a LANDSAT image into areas of similar spectral response. By stratifying the area, fewer samples are required to characterize each region. In addition, the averaging of multiple samples within each strata will reduce the affect of errors associated with sample point location and changes in soil brightness. The design of a stratified sampling scheme coupled with the use of global positioning devices should improve the distribution and location of sample points within the each strata.

Other research plans and direction include:

Continuing development of a spatial modeling tool called GRIDS (Geographically Referenced Information Delivery System), which is capable of accepting and outputting geo-referenced data within a spatial framework. GRIDS will have the capability of integrating SPUR modeling output and remote sensing information within a geographic information system called GRASS (Geographical Resource Analysis Support System) and an image processing package called ERDAS (Earth Resources Data Analysis System). Combining spatial technology with system modeling will allow the simulation of system processes within a space-time framework.

Enhancing our understanding of plant/animal interface. This work is necessary if we wish to develop new and improved resource management strategies and influence policy concerning our national grazing lands.

Continuing analysis of field data in conjunction with remote imagery and simulation models. This will include the development of interfaces that allow for including ground data into simulation models and the subsequent filtering of the output to allow for real-time simulations.

We have developed a range-dependency index for the United States. The theory behind the index should be applicable to other agricultural groups, such as wheat and corn. We will work at developing such indices.

ANALYSIS OF CHANGES IN SOIL CARBON BALANCE

C.V. Cole
Great Plains Systems Research Unit

CRIS: 5402-11000-002

The following work was conducted in collaboration with the Natural Resource Ecology Laboratory, Colorado State University.

The **CENTURY** model was modified to schedule a sequence of management events in a variety of cropping systems. A preprocessor called *event100* was written to schedule management events, the growth of different crops in rotation and to control the overall execution of the **CENTURY** model. The management events and crop growth controls which can be implemented by *event100* are crop type, planting and harvest months, first and last month of growth (for grassland or perennial crops), senescence month, cultivation, fertilizer addition, irrigation, addition of organic matter (straw or manure), grazing, fire and erosion. The scheduling of crop rotations and management events uses the principle of repeating sequences within blocks of time. Block with different sequences can be appended in *event100* and run in succession in the **CENTURY** model. For example, a series of historical farm practices such as breaking of the native sod in 1920, a wheat-fallow rotation with plow cultivation and straw removal until 1940, wheat-fallow with stubble-mulch management until 1980, followed by wheat-sorghum-fallow can be scheduled. For grain crops a harvest index based on a genetic maximum and moisture stress in the two months prior to harvest is calculated. The crop harvest routine also allows for the harvest of roots, hay crops or straw removal after a grain crop. The model can simulate a variety of conventional cultivation methods, such as plowing or sweep tillage, thinning operations or herbicide application. A revision of the decomposition submodel including an additional suite of pools for microbial biomass in surface litter is currently being implemented with the new version of **CENTURY**.

MEASURING AND MODELING THE EXCHANGE OF GREENHOUSE GASES BETWEEN SOIL AND ATMOSPHERE

M.J. Shaffer and R. Lapitan
Great Plains Systems Research Unit

CRIS: 5402-11000-002

PROBLEM: Improved capabilities are needed to predict long-term and large-scale changes in agroecosystems carbon balance and productivity in response to changes in climate and management practices. In particular, models are needed to predict the movement of greenhouse gases from and into the soil profile.

FINDINGS: Work progressed on the development of a comprehensive simulation model for the release and absorption of greenhouse gases by soils. The existing NTRM-2D model which includes provision for water, heat, and solute fluxes in 2-dimensions was refined for use on personal computers, and studied for inclusion of gas transport and reaction submodels. The literature was reviewed to identify potential gas transport models suitable for use within the context of the NTRM-2D model. Field data, including climate, topographic features, management practices and soil properties taken from a shortgrass steppe and a long-term cropping systems study in Colorado, were obtained to further improve the subcomponents of the NTRM-2D model and provide a historical database for the gas transport model being developed. An updated version of the RZWQM carbon and nitrogen transformation model (OMNI) was developed that includes provision for greenhouse gas absorption from and release to the soil atmosphere. This model will be included in NTRM-2D along with a convective and diffusive gas transport submodel. A prototype soil-gas probe and field soil-gas sampling techniques are being developed for a better handle on the spatial variability encountered in soil-gas measurements, i.e. along and across the crop rows and along the vertical soil profile. (In cooperation with C.V. Cole, J. Hanson, and A. Mosier).

FUTURE PLANS: A field plot study will be started in 1992 to collect soil gas samples (CO_2, N_2O, and CH_4) and other supporting data suitable to develop and test a soil gas flux and reaction submodel. We also will be working on a merge of the 2-dimensional NTRM water, heat, and solute transport submodel with the crop-weed interaction submodel. We will also work on the user interface portion of the overall 2-D model in an attempt to make this complex model easier to use and operate. (In cooperation with Rakesh Bahadur, Carlos Alonso, Laj Ahuja, Vern Cole, and A. Mosier).

EFFECTS OF PROJECTED GLOBAL CLIMATE CHANGE ON RANGELAND AND LIVESTOCK PRODUCTION

Jon D. Hanson
Great Plains Systems Research Unit

CRIS: 5402-11000-002

PROBLEM:

Climate change has become a major concern among many scientists. Atmospheric CO_2 concentration has increased 25% in the past 70 years. At present rates of increase, CO_2 will reach a concentration twice that of pre-industrial times within the next 75 years. Concentration of other greenhouse gases (e.g., methane, nitrous oxide, and chlorofluorocarbon compounds) are also increasing. Escalating concentrations of these gases absorb thermal radiation which subsequently warms the earth's atmosphere. General Circulation Models (GCMs) of the atmosphere suggest the average global temperature will increase by as much as 3°C to 5°C as atmospheric CO_2 levels double. GCMs also predict an increased rate of circulation in the global hydrologic cycle, which could lead to increased precipitation. However, GCMs cannot reliably predict regional-scale climate change, the vital information that is needed to estimate the potential impact of climate change on agricultural production.

As CO_2 increases, plant communities will change and species will populate areas that were previously inaccessible. Other changes that could possibly take place include modified rooting patterns, increased seed germination and plant establishment, and increased nitrogen fixation. These changes could have direct repercussions on the Conservation Reserve Program aimed at returning marginal cropland to rangeland. Thus, the ultimate effect on rangeland could end up being positive especially for areas presently considered too dry for contemporary crop production. However, higher production does not necessarily mean increased agricultural sustainability. On the contrary, production increases could lead to decreases of soil organic matter and subsequent degradation of the rangeland ecosystem. If these systems are to remain stable, care must be taken to monitor livestock production systems for excessive removal of soil organic matter.

The objectives are:

1. Assess the impacts of climate change on livestock and grassland production in the major producing regions of the United States and

2. Identify and evaluate adjustments in practices and government programs and policies that would facilitate adaptation to climate change.

APPROACH:

A dual emphasis was used to conduct this project. We first set out to determine where grazing is the most economically important. As a result, we developed what we call the Range Dependency Index (RDI). A map of the index shows how important range cattle production (cattle not sold from feed-lots) is to many of the counties within the Great Plains and Northwest. In Nebraska, for example, the RDI reaches a high of 46%, i.e. 46% of the county's income is from the sale of unfed beef-cattle.

Our second emphasis was on evaluating how climate change will potentially effect those regions of the United States that have a high dependency on grazing cattle. During this phase of the project, much time was spent on validating our simulation tool to make certain it performed well enough to answer these important questions. Simulations were conducted for areas of the U.S. with high RDI values. Eleven indicators were examined to determine the fate of grazing lands under four different climate change scenarios. The indicator variables included: peak standing crop, carbon to nitrogen ratio, water-use efficiency, soil organic matter, soil inorganic nitrogen, intake of grazed forage, digestibility of the grazed diet, forage to supplement ratio, milk production, and cow and calf weights at weaning. The climate change scenarios were effective doubling of CO_2 (550 ppm) alone and changes in precipitation and temperature associated with an effective doubling of CO_2 as predicted by three general circulation models: Geophysical Fluid Dynamics Laboratory (GFDL), Goddard Institute for Space Studies (GISS), and the United Kingdom Meteorological Office (UKMO).

FINDINGS AND INTERPRETATIONS:

Doubling of CO_2 alone caused only slight increases of plant production, but when CO_2 doubling was coupled with changes in precipitation and temperature, plant production increased significantly. The most limiting factors on rangeland are moisture and available nitrogen. Thus as expected, moisture accounted for the greatest increases in plant production. Yet, wet/dry cycles have tremendous consequences on rangeland production. Normal, periodic drought is as important an issue as man induced global climate change when considering agriculture in arid and semiarid lands.

Generally, both plant and animal production responded positively to climate change for the northern latitudes. However, higher production did tend to reduce the soil organic matter, increasing the chance for system degradation. Sustainability of long-term agriculture is necessary for a stable agricultural economy within the United States. Therefore, we must consider not only short-term economic trends, but also long-term ecological stability. To safeguard rangeland, a system should be implemented for long-term monitoring of soil organic matter. Animal production was, however, severely hampered in the southern regions of this study. The primary cause was the direct effect of temperature on the animals and the indirect effect of temperature on forage quality. Management may, however, compensate for this problem by selecting other breeds of animals, particularly Bos indicus.

Six key points were inferred from these simulation experiments. Firstly, the climate-change scenarios tended to predict an increased length of growing season. Grasslands rely mostly on spring moisture while summers are generally very dry. The GCMs seemed to accentuate this pattern and as a result the growing season was longer (by some 30 days). Subsequently, production increased, particularly in the spring and fall. Secondly, animal production decreased for the California and Southern climate change scenarios. Reduced animal production occurred coincident with increased plant production because of decreases in soil inorganic nitrogen and concomitant decreases in forage quality. The availability of nitrogen in rangeland systems is a controlling factor and is closely related to the decomposition of soil organic nitrogen. Thirdly, livestock production tended to shift northward because of adverse conditions (primarily high temperatures) in the southern regions. Fourthly, climatic variance between years was slightly greater for the scenarios than for the nominal run. If the variance for yearly production does indeed increase, then uncertainty regarding plant growth increases thereby resulting in uncertainty in management decisions. Fifthly, management will be able to compensate for climate change. Management of livestock will ultimately guide animal performance. In bad years the manager must either sell livestock or feed them. If vegetation production is more variable, then stocking rates must be decreased to reduce risk and to insure good animal vigor. And finally, intensive management costs money. The more intense the management, the more the cost to the operator. Thus, even though the livestock may perform at similar levels, in the end, beef productions costs may increase.

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EFFECT OF IMBITITIONAL TEMPERATURE ON WINTERFAT SEEDLING VIGOR

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Rangeland Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM: Seedling mortality is a major reason for stand failure from direct seeded shrubs. To reduce mortality we need to better understand the factors influencing seedling vigor. In 1990 I reported that imbibition at 20°C resulted in significantly less vigor than when seeds were imbibed at 5°C. The reason for this effect is not known, but two alternative hypothesis were suggested. Rapid imbibition at warmer temperatures may damage seed membranes; or waste respiration, exacerbated by warm temperatures, may significantly decrease post-imbibition respiration substrate.

APPROACH: The imbibition pattern in winterfat seeds was investigated in cooperation with M.B. McDonald (Ohio State Univ.). Winterfat seeds with the pericarp removed were submerged in beakers of water, or in 1% sodium hypochlorite solutions, and imbibed at 4 and 25°C for 1, 4, and 8 hours. The seeds were weighed, or were analyzed (EDAX) for Cl^- to measure movement of water into the seed. In an associated study a "Micro-Oxymax" respirometer was used to monitor oxygen consumption and carbon dioxide production during seed imbibition, germination, and early seedling growth. Measurements were made on groups of 20 seeds. The seeds were imbibed for 4 days at 5 or at 20°C. Respiration was measured by sampling the respiration chamber headspace at 4 hour intervals during imbibition and through a subsequent 68 hours in which both treatments were held at 20°C. The test was conducted for 2 ecotypes.

FINDINGS: Both the EDAX analysis and the fresh weight gain indicate that at 25°C the majority of imbibition occurred within the first hour. After 8 hours at 4°C, fresh weight gain was 91% of the gain measured after 1 hour at 25°C. In the respiration study, seeds imbibed at 5°C maintained a higher average respiration rate ($P<0.01$) when compared over all sample periods during the 68-hour post-imbibition period. The results from both studies support membrane damage as a factor reducing vigor of seedlings when seed is imbibed at 20°C.

FUTURE PLANS: Continue to investigate the imbibition pattern in winterfat seeds and diaspores with special emphasis on the question of membrane damage during imbibition at warm temperatures. We are also continuing work now under way to test other species for excessive seed weight loss at high imbibition temperatures and corresponding negative effects on seedling vigor. Finally, respirometry methods are being improved and the new methods will be used in an attempt to measure respiration of individual seeds.

STUDIES OF BITTERBRUSH SEED DORMANCY

D. T. Booth
Rangelands Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM: The use of bitterbrush in revegetation projects, and the analysis of bitterbrush seed quality, is hindered by seed dormancy. Known chemical treatments to remove seed dormancy are only partially effective in enhancing germination, are banned for use on public lands because of carcinogenic chemicals, or are of questionable value for seedling establishment. There are two theories to explain bitterbrush seed dormancy. The hypoxia theory ascribes dormancy to seed coat-imposed embryo hypoxia. The alternative is that dormancy is due to a chemical inhibitor whose mode of action is not known. Studies at my laboratory suggested that dormancy is not due to embryo anaerobiosis. Therefore, I began studies to test for a site of action by a chemical inhibitor and to learn if standard seed treatments (to enhance germination) stimulate the embryo or act on an inhibitor.

APPROACH: The hypothesis I tested is that seed coat chemicals inhibit glycolysis. This was tested by extracting the chemicals from the bitterbrush seed coat, separating these into phenolic and cucurbitacin fractions, and testing for glycolytic inhibition by analyzing for ethanol following anaerobic incubation of a yeast and sucrose mixture. As reported last year, I found mixtures containing the extracts to have less ethanol ($P < 0.05$) than mixtures without extract, implying that chemicals in the bitterbrush seed coat have the potential to interfere with glycolysis. This year the test was used as a bioassay for different inhibitor extraction methods in cooperation with Gayland Spencer at USDA-ARS-NCAUR in Peoria. Also, I began testing seeds treated to enhance germination.

FINDINGS: Most of this year's work concerned bioassays of seed extracts sent to us from Peoria. The first bioassays resulted in the highest concentration of extract producing the most ethanol. The distilled water check, which we expected to have the highest ethanol concentration, had the lowest. Since I didn't believe our results, we spent some time trying to figure out better methods, and we retested our original experiment using smaller volumes of solution (as in the bioassay procedure). We did not develop methods that gave significantly less variation than our original methods. Our retest gave the same results as in the original experiment, so we used the bioassay on the remaining extracts. We found these extracts to have lost weight during storage, and in contrast to the first extracts tested, gave the expected decrease in ethanol with increasing concentrations of extract. Other work is still in progress.

INTERPRETATION: There appears to have been a volatile constituent in the Peoria extracts that confounded the bioassay. This was lost during storage. Retesting the original experiment and having the same result increases confidence in the procedure.

FUTURE PLANS: I will continue current work by using the bioassay to test extracts from seed treated with standard chemical treatments for inducing germination. I expect significantly less glycolytic depression from extracts of treated seed. If this is true I will conclude (1) that the seed dormancy model should include glycolytic interference by seed coat chemicals and, (2) that the chemical treatments used to induce germination act on seed coat chemicals rather than on the embryo. I will then look for new methods for removing seed dormancy based on a new model of dormancy in bitterbrush seed.

ALFALFA

C. E. Townsend
Rangelands Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM: The yellow-flowered alfalfas (Medicago sativa subsp. falcata) are better adapted than the purple-flowered alfalfas (M> sativa subsp. sativa) to the harsh range sites of the central and northern Great Plains. Unfortunately, the falcata-types have smaller seeds and lack the excellent seedling vigor of the sativa-types.

APPROACH:

Seed Weight: Six-seed-weight classes (1.00-1.19, 1.20-1.39, 1.40-1.59, 1.60-1.79, 1.80-1.99, and 2.0+ g/1000 seeds) have been evaluated for seedling emergence in the field from three depths of planting (1.3, 2.5, and 3.8 cm) since 1987.

Germplasm: Plants for four germplasms were selected from the spaced-plant nursery established in 1986. In three of the germplasms, plants were selected for *falcata* traits such as small leaflet size, orange colored flowers, sickle-shaped pods, good mature plant vigor, and generally a prostrate growth habit. Within this group three different seed size classes were selected; namely, 1.00-1.59, 1.60-1.79 and 1.80+ g/1000 seeds. Each of these three groups of plants was placed under pollination cages. The fourth germplasm consisted of a group of plants which had the ability to spread. Some of the plants selected for the latter germplasm were not as typical *falcata* types as in the other three germplasms.

Drought Tolerance: Propagules of 19 clones (2 sativa and 17 falcata) were established at the CPER. The falcata clones were selected for variability in general vigor, growth habit (erect or prostrate), and leaflet size. The experimental design was a randomized complete block with 10 replicates. A plot consisted of a single row of five propagules per clone placed on 2-ft centers. All plants (propagules) were separated by single rows of Hycrest crested wheatgrass seeded in 2-ft grid pattern. This is a cooperative study with J. Morgan and D. LeCain on the relationship of plant morphology and photosynthetic rates with drought tolerance.

FINDINGS:

Germplasms: The three seed size germplasms were consolidated into one. They were not covered with a pollination cage because they were reasonably well isolated from other alfalfa plantings. Pollination cages were placed over the tetraploid germplasm and the germplasm selected for ability to spread. Honey bees served as pollinators. Seed yields were generally good; however, some plants were sterile. Because the CSU Agronomy Farm has been sold, we moved plants from these two germplasms as well as the diploid germplasm to an area we control near our seed processing and storage building.

Soil Weight: This study was completed and the data is reported in a manuscript.

Drought Tolerance: Forage yield of individual clones was obtained, but the data have not been analyzed (This is a cooperative study with D. LeCain and J. Morgan).

INTERPRETATION: We were successful in improving the seedling emergence of yellow-flowered alfalfa by selecting for increased seed weight.

FUTURE PLANS:

Germplasms: Increase of the 2n and 4n germplasms will continue.

General: The cooperative study with D. LeCain and J. Morgan will continue. In addition, the cooperative study with the late Jim Forwood and J. Morgan will continue.

CICER MILKVETCH

C. E. Townsend
Rangelands Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM:

Although considerable progress has been made in the"domestication" of cicer milkvetch, much remains to be done. There is a need (a) for improved stand establishment following seedling emergence and (b) for the development of germplasm from the selections that have the ability to produce substantial regrowth during the third growth cycle (Aug. 1 through Sept. 15). The latter should result in the production of an experimental synthetic with a forage yield similar to that of alfalfa.

A relatively new problem concerns the apparent photosensitivity reaction developed under some environments by sheep and cattle grazing pure stands of cicer milkvetch. This problem appears to be the most severe in Minnesota and to a much lesser extent in Nebraska. We have not observed the problem in grazing studies with sheep at Fort Collins. Also, it has not been reported elsewhere.

There is a need for a post-emergence herbicide to control broad-leafed weeds in seedling stands of milkvetch. Previous research has demonstrated (a) that 2,4-D amine has the potential of doing the job and (b) that variability exists within the species for tolerance to 2,4-D amine.

APPROACH:

Selection for improved forage yield: Selection and evaluation of milkvetch progenies for ability to produce substantial regrowth during the third growth period (Aug. 1 to Sept. 15) was completed. Two cycles of simple recurrent selection for improved forage yield and greater plant height, especially during the third growth period, improved total forage yield substantially. The 15 parental clones whose polycross progenies gave the best performance were selected as parental clones for a new variety.

2,4-D amine tolerance: Simple recurrent selection has been used to increase the tolerance of cicer milkvetch to 2,4-D amine in a greenhouse environment. Six cycles of selection have been completed.

FINDINGS:

Forage yield: The Varietal Release Committee of Colorado State University approved the release of the new cultivar selected primarily for improved forage yield during the third growth period. The variety was named Windsor. The Colorado Crop Improvement Association contracted with the Wyoming Crop Improvement Association to produce foundation seed of Windsor. Therefore, we delivered about 0.5 kg of breeder seed to the WCIA who then contracted with a seed producer in the Powell, Wyoming area. Although the foundation seed field was not planted until late June 1991, seedlings had reached a height of about 20 cm by mid September.
Superior plants in the second cycle of selection (Williamson farm) were dug and placed in three isolation blocks for the production of improve germplasm. The elite plants were as follows: (a) 11 plants for superior height, (b) 33 plants for superior height and forage yield, and (c) 29 plants for superior spread and generally good vigor.

Parental clones of the cultivar Monarch: These clones were removed from the CSU Agronomy Farm and transplanted to the Cheyenne Station. This was done because the old agronomy farm has been sold and the new farm has not been developed yet.

2,4-D amine tolerance: Seedlings from 5 cycles of simple recurrent selection were evaluated for tolerance to 2,4-D amine (1 kg ha^{-1}) in the greenhouse. There were 56, 85, 90, 118, and 100 polycross progenies in cycle 1, 2, 3, 4, and 5, respectively. Each entry (449 progenies) was represented by one 10 cm dia. pot with five seedlings per replicate. The experimental design was a randomized complete block with nine replicates. Unfortunately, data were useable from only four replicates. The other five replicates were destroyed by unauthorized use of a volatile herbicide which came through the intake ducts of the greenhouse. The data for the four replicates have not been completely analyzed.

Forage yield: We were successful in combining the increased forage yield due to an insensitivity response to decreasing photoperiods in mid to late summer with the excellent yields of the first and second growth periods. Forage yields of this germplasm should be similar to that of alfalfa.

FUTURE PLANS:

Forage yield: Provided the seedlings of the foundation seed increase over winter and produce a seed crop, the new cultivar will be officially released in the fall of 1992. We are also investigating the possibility of an exclusive release.

Germplasms: Collect seed from the three germplasms described above. A release notice is being prepared for four germplasms that have been developed over the past 20 years. They were selected for early seedling vigor and mature plant vigor under irrigation or for persistence under dryland. This is a cooperative release involving ARS, the Colorado Agricultural Experiment Station, and the Montana Agricultural Experiment Station.

Photosensitization: The research associate position awarded to Dr. Sue Martin, Sugarbeet Unit, and myself was filled in October 1991 by Dr. Andrew W. Lenssen. We will be trying to identify the compound(s) that are related to the apparent photosensitivity issue. An 8.1 ha planting of cicer milkvetch and brome grass will be made in the spring of 1992. This planting will be irrigated and used for grazing by sheep to investigate the sensitivity of sheep to photosensitivity postulated to occur from grazing cicer milkvetch.

2,4-D amine tolerance: The data collection from the four replicates will be analyzed and we will proceed from there.

Tolerance to low pH soils: A follow-up study was initiated in the greenhouse last month. This is a cooperative study with Dr. R. Bowman.

INVESTIGATE TRAITS RELATED TO DROUGHT RESISTANCE AND WATER-USE-EFFICIENCY AMONG MEDICAGO FALCATA TYPE ALFALFA ACCESSIONS

Jack A. Morgan
Rangelands Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM:

There is interest in introducing legume plant species to arid rangeland because of their high nutritional quality and their ability to fix atmospheric nitrogen and improve soil conditions. Field trials have indicated that legumes improve range livestock production.

Commonly-grown alfalfas are primarily Medicago sativa L. varieties, which typically have high water requirements and are therefore unsuitable for Great Plains rangelands. Medicago falcata L. alfalfas, however, are considered to be more drought resistant than sativa-types, but are not commonly used in breeding programs because of their small seed size, poor seedling vigor, small leaves and stemmy growth habit, which limit their utility in areas with adequate water. A program to select for falcatas with large seed and good seedling vigor is underway, but almost no information describing variability of falcata alfalfas for traits relating to drought resistance and water-use-efficiency is available. Such information may facilitate breeding for better adapted rangeland cultivars.

APPROACH:

Alfalfa Germplasm Studies: Clonal propagules of nineteen falcata and sativa alfalfas were transplanted into native rangeland at the Central Plains Experimental Range (C.P.E.R.) during the spring of 1989. During the summers of 1990 and 1991, soil moisture within the plant root zone was monitored using the Time-Domain-Reflectometry (T.D.R.) technique. Plant water potential was measured at the same time so plant responses to seasonal soil water depletion could be investigated. Plants were harvested early to mon June both years and separated into leaf and stem material, and dried for herbage production and carbon isotope content.

Growth and Physiology of Alfalfa/Crested Wheatgrass: In spring 1990, field plots containing three alfalfa accessions, with and without crested wheatgrass, and crested wheatgrass alone, were established at the C.P.E.R. An irrigation treatment was applied to half of the plots via trickle-tube. Each treatment was replicated four times in each of four completely randomized blocks. Neutron access tubes were installed to monitor soil water content. A good stand was established in 1990, and plots were mowed once in mid-summer.

Experimental measurements began in spring of 1991. Soil water content, leaf water potential and growth stage were periodically monitored. A harvest was conducted in mid-June and material collected for above-ground biomass, including leaf and stem fractions, forage quality analysis, and carbon isotope analysis.

FINDINGS:

Alfalfa Germplasm Studies: Differences in water potential were observed among the 19 alfalfas on most dates, in agreement with the results of the previous year. Significant differences for leaf production, stem production and leaf/stem ratio were found for the 19 alfalfas. Sativa accessions tended to be larger and have higher water potentials than the falcatas.

Probably most interesting was the finding that tissue carbon isotope composition varied significantly among the cultivars, and that strong correlations (as high as 0.8 **) were observed between measurements obtained from greenhouse-grown plants (work done in 1989 and 1990) and field plants (1990 and 1991 field seasons). This suggests a strong genetic component for carbon isotope discrimination in falcata alfalfa. As carbon isotope composition is theorized to relate to plant water use efficiency, these results suggest promise for using this technique to improve and select for drought-tolerant legumes for the semi-arid range.

Growth and Physiology of Alfalfa/Crested Wheatgrass: The results from this first year are still being analyzed, although some preliminary analyses are worth mentioning. Not surprisingly, above-ground production was significantly influenced by irrigation treatment and planting treatment (seven treatments consisting of three alfalfa accessions, alone and in combination with crested wheatgrass, and crested wheatgrass alone). The highest productivity was achieved by a combination of a falcata accession and crested wheatgrass, while crested wheatgrass alone was the low yielder. The crested wheatgrass grown without a legume appeared to be a lighter shade of green compared to that grown in combination with the alfalfa genotypes, a result which will likely be reflected in the forage quality assays when completed. No significant interactions of irrigation X planting treatment were observed for yield, and irrigation improved productivity only 23% averaged over all planting treatments. We suspect that some irrigation water required in the previous year for establishment of all plots may have been stored in the soil, thus reducing the irrigation response in 1991. Analysis of neutron probe data will help clarify this and other aspects of the experimental results. We are still waiting to receive the results of the carbon isotope test and forage quality analysis.

FUTURE PLANS:

Alfalfa Germplasm Studies: We will be testing more alfalfa germplasm of C.E. Townsend's for variation in carbon isotope composition. These results plus those already obtained from the 19 genotypes will be used to select a group of genotypes for propagation and eventual transplanting (1993) in a field study with a line-source irrigation system. The field study will involve evaluating how the genetic-related variation in carbon discrimination as affected by water supply. Greenhouse studies are also planned for these genotypes to understand the basis for the genetic variation in carbon discrimination. That variation could be due either to photosynthetic capacity, plant diffusive conductance, or a combination of the two. The implications of the carbon isotope signatures resulting from carbon discrimination will depend on the degree to which the trait is influenced by photosynthesis or diffusive conductance.

Growth and Physiology of Alfalfa/Crested Wheatgrass: Our studies will continue evaluating the growth, quality and water use of the alfalfa/crested wheatgrass combinations. Continued analysis of the 1991 data set will continue. The plots will be sampled in an attempt to evaluate soil nitrogen contribution from the alfalfa.

DETERMINE PHYSIOLOGICAL/MORPHOLOGICAL RESPONSES OF C3 AND C_4 RANGEGRASSES TO INCREASED ATMOSPHERIC CO_2 CONCENTRATIONS AND ASSOCIATED CLIMATE CHANGE

Jack A. Morgan
Rangelands Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM:

Historical trends and current projections of future patterns in atmospheric CO_2 levels strongly indicate a continued enrichment in global CO_2, with some projections indicating a doubling of present levels over the next 100 years. Projections of CO_2-induced climate changes are less certain, but include a variety of scenarios including altered rainfall patterns and temperature regimes. As plant growth is responsive to CO_2, temperature and water, changes in the global climate are bound to have significant impacts on agriculture. However, the specific plant responses are presently unknown due to limited knowledge of physiological responses of plants to combined alterations in ambient CO_2 concentrations, temperature and water availability. To date, most CO_2 and global climate work has been conducted within the context of cropping systems. Effects of global climate change and CO_2 enrichment on range plant communities remain relatively unexplored, despite the importance of the latter in terms of acreage and economy in the semi-arid West.

Experimentation is needed to understand the responses of range grasses to CO_2 and temperature, and the consequences for competition among them.

APPROACH:

Duke Study: In 1990, soil cores containing western wheatgrass (*Agropyron smithii* Rydb.) and blue grama (*Bouteloua gracilis* (H.B.K.) Griffiths), important C_3 and C_4 grasses of the Great Plains, were extracted from the Central Plains Experiment Range (CPER) near Nunn, CO, put in soil columns, and transported to the Duke Phytotron at Duke University, Durham, NC. Columns were assigned to four growth chambers maintained at two CO_2 (ambient and approximately twice ambient) and two temperature regimes. Temperature regimes were ramped up and down daily and adjusted according to seasonal norms. Photoperiod was also maintained to simulate seasonal patterns for the CPER. No fertilizer was added to the columns, and irrigation was provided to simulate patterns typically encountered at the CPER. Gas exchange and related measurements were obtained on plants during the early summer phase of the environments. Measurements included CO_2 response curves of single leaf photosynthesis, leaf nitrogen concentrations, and stomatal density counts. Additional soil microbiological and nutrient information was gathered by collaborating scientists. Measurements in 1991 represented the third growth cycle.

Crops Research Lab Study: This study was initiated to investigate the biochemical causes of photosynthetic acclimation of blue grama and western wheatgrass to enriched CO_2 levels. We found evidence in the Duke study that plants exposed to continuously high CO_2 concentrations had lowered photosynthetic capacity compared to plants growing under current CO_2 levels. Growth chambers at the Crops Research Lab were modified to control CO_2 with a computerized control system, and a series of investigations began to examine carbohydrate metabolism in conjunction with photosynthesis of blue grama and western wheatgrass grown under enriched and current ambient CO_2 levels, and at two temperature regimes. John Read, a Research Associate hired to conduct these studies, will travel to

Logan, Utah to develop the procedures required to analyze plant samples for a variety of carbohydrate fractions. We hypothesize that the lowered photosynthetic activity observed in plants grown at high CO_2 levels is due to the accumulation of leaf carbohydrates, although at present we do not know which fractions may be responsible for the apparent photosynthetic inhibition.

FINDINGS:

Duke Study: Leaf photosynthetic activity of western wheatgrass was found to be considerably more responsive to CO_2 than photosynthesis of blue grama. On the other hand, stomates of blue grama closed more in response to elevated CO_2 than western wheatgrass. As a result, water use efficiency (photosynthesis/transpiration ratio) increased similarly in both species in response to elevated CO_2. This similar CO_2-response of water use efficiency in the C_3 (western wheatgrass) and C_4 (blue grama) grass is contrary to previous work which suggests greater enhancements of WUE in C_3 species. Our study suggests no clear advantage between photosynthetic types in terms of CO_2-induced changes in WUE.

Plants grown at high CO_2 levels tended to have lower photosynthetic capacities, especially ones grown at high temperatures. These results are similar to those made in previous growth cycles. We suspect these photosynthetic acclimations to high CO_2 result from the inability of plants to translocate carbohydrates to the actively growing sinks. The accumulation of leaf carbohydrates presumably inhibits photosynthesis. This hypothesis is the cornerstone of our new research thrust at the Crops Research Lab (above). Another possible explanation for the reduced photosynthetic capacity of plants grown at enriched CO_2 levels is that early CO_2-induced growth responses depleted readily-available soil N in the enriched CO_2 treatment, thereby reducing photosynthetic capacity through N deficiency. This possibility is presently being examined in data analysis of the Duke study, and through modeling studies, using the Grassland Ecosystem Model (Hunt et al., 1991).

Crops Research Lab Study: We are currently in the second growth chamber cycle of this study. No meaningful data analysis and presentation is presently possible.

FUTURE PLANS: We will continue to evaluate these research findings as more data are available and analysis continues. Two manuscripts are in progress, summarizing the Duke Study findings. Modeling studies are planned with H.W. Hunt to extrapolate these findings, and a combined experimental/modeling study has been planned with H.W. Hunt and W.G. Knight (Earth Sciences Group) to understand how elevated CO_2 regimes might influence carbon partitioning to roots and mycorrhizae, and how that partitioning might influence the responses of range grasses to altered CO_2/temperature environments. A proposal was submitted on 3 February 1992 to CSRS for funding this study with Hunt and Knight.

DETERMINE THE PHYSIOLOGICAL/MORPHOLOGICAL BASES FOR VARIATIONS IN WATER-USE-EFFICIENCY, DROUGHT RESISTANCE, PRIMARY PRODUCTION AND YIELD IN WINTER WHEAT DUE TO VARIETAL DIFFERENCES AND THE ENVIRONMENT

Jack A. Morgan
Rangelands Resources Research Unit

CRIS: 5409-11210-001-00

PROBLEM: In the semi-arid Great Plains of the United States, water is the most limiting resource in crop production systems. Considerable evidence indicates that genetic variability exists in domesticated wheat for traits that are thought to impart adaptability to water-limited environments. A better understanding of the physiological bases underlying wheat adaptation to water-deficit stresses and the potential response of this crop within the framework of conservation-production systems is needed before significant improvements can be made in matching the genetic potential of the crop with its environment.

APPROACH:

Stress Physiology in Wheat: A series of laboratory studies were conducted in efforts to better understand genotypic-related variations in 1) single leaf and canopy gas exchange, including photosynthetic capacity and water-use-efficiency, and 2) internal water relations. We are attempting to understand water-use-efficiency and drought resistance at the organ level, drawing on some characteristics at the cellular level. Growth chamber studies were concluded evaluating how water stress, including stress conditioning, effect physiological responses in three winter wheat genotypes. Two of the genotypes have been identified as stress resistant, the other stress susceptible. The two stress resistant genotypes include one which tolerates low leaf water potentials, and another which avoids desiccation. Detailed internal water relations, biochemical analyses and gas exchange measurements were conducted on plants to determine the underlying mechanisms behind different genotypic responses to stress regimes (e.g., short-term, rapidly-imposed stress vs. long-term, acclimating stress). Ridge National Lab).

CO_2 Response of Wheat: Winter wheat was grown in growth chambers at current ambient CO_2 levels (350 uL L^{-1}) and 650 uL L^{-1}. Measurements of plant morphology, development, shoot/root dry matter partitioning, leaf gas exchange, and leaf carbohydrate analyses were conducted to determine the response of wheat to elevated CO_2.

FINDINGS:

Stress Physiology in Wheat: We conducted extensive tests in preparation for the growth chamber-stress study, including analyzing and calibrating stem-flow gauges, practicing pressure volume curves with psychrometers and pressure chambers, and setting up a controlled environment gas exchange system. Our studies confirmed the unique water relations of one cultivar, 'Sandy', which despite being a drought resistant cultivar, has characteristically low water potentials. More importantly, we quantified the effect conditioning has on stress susceptibility in wheat. Changes in osmotic adjustment and the bulk modulus of elasticity were altered from long-term exposure of plants to a dwindling soil water supply. These alterations resulted in less desiccation potential compared to plants subjected to a short-term stress which

did not allow any beneficial conditioning. These findings will help scientists understand how plants adapt to water stress, and will be useful in modeling, management and breeding programs.
We have abandoned the use of the stem-flow gauge measurements in the study because of unreliable results in a small stem species like wheat.

CO_2 Response of Wheat: Gas exchange and growth analyses were completed. Briefly, we found growth and yield to be enhanced by growth of plants in the high CO_2 regime. Photosynthesis was also higher for the plants grown at enriched CO_2 levels, although CO_2 response curves of photosynthesis suggested a lowered photosynthetic capacity compared to plants grown at current ambient CO_2 levels. Leaf samples have not yet been assayed for carbohydrate analyses to determine whether leaf carbohydrate levels were sufficient to induced photosynthetic inhibition in wheat grown at the high CO_2 regime.

FUTURE PLANS: Due to the re-organization of research units in Fort Collins, and my transfer to the Rangeland Resources Research Unit, I will suspend all research activities in wheat, and instead will focus on range related issues. I have five manuscripts that I will be involved with as author or co-author in publishing, and plan on finishing most of those in 1992.

MANAGEMENT OF RANGELAND SURFACE WATERS TO IMPROVE RANGE PLANT ESTABLISHMENT AND PRODUCTIVITY

G.W. Frasier and J.R. Forwood
Rangelands Resources Research Unit

CRIS: 5409-12130-001-00

PROBLEM: Plant establishment from seed in semiarid regions under natural precipitation regimes is difficult because of the short time frame when soil moisture is favorable for seed germination and seedling establishment. Rainfall occurrences are highly variable, even in the "rainy" season. The dry periods between events are usually of longer duration than the length of the wet periods. The timing and quantity of precipitation events immediately following seeding can have lasting effects. Understanding the relations between water availability, seed germination, and seedling establishment will improve the chances of successful plant establishment in semiarid regions with natural rainfed conditions.

APPROACH: Greenhouse studies were conducted to determine seed germination and seedling establishment characteristics of selected range grasses, forbs, and shrubs as affected by various combinations of the initial lengths of wet-dry, dry-day watering sequence. These survival characteristics are used to develop a analytic, stochastic, and simulation models of seed germination and seedling emergence as affected by stochastic rainfall inputs. The seedling emergence and survival responses are combined with probability models of natural rainfall drought occurrence combinations for optimizing the time for seeding or selecting the proper species to seed in a given climatic regime. These techniques, utilizing existing climatic, soil and crop data, reduce the time and work required to evaluate the effect of precipitation variability (quantity and timing) on the establishment and growth performance of various rangeland and agronomic plants.

FINDINGS:

Greenhouse studies showed that blue grama seedlings begin to emerge in 3 to 4 days after a single watering event. If there is no additional water, the seedlings started to die at 5 to 7 days. Even with 3 wet days, there was some seedling die-off with 10 days dry. As the wet period is extended the seedlings begin to die at an increasing rate. Some seedlings can survive dry periods of 15-20 days. For successful seedling establishment, a second wet period is required about 2 to 3 weeks after the initial wet period.

Combining the seedling establishment characteristics of blue grama with rainfall probability of wet-dry sequences in the central great plains area indicates that the chances of receiving favorable precipitation patterns for seedling establishment is about 1 in 500 to 1000 years.

INTERPRETATION: Understanding the basic plant-water relations and seedling survival responses during initial plant establishment periods in combination with rainfall occurrence probability analysis will assist in the development of techniques for changing the plant species composition in an area.

FUTURE PLANS: The studies will be expanded to include other plant species such as cool season grasses, forbs, small shrubs and small grains of potential suitability for use with runoff farming techniques.

RUNOFF/INFILTRATION MANAGEMENT FOR IMPROVED FORAGE PRODUCTION

G.W. Frasier and J.R. Forwood
Rangelands Resources Research Unit

CRIS: 5409-12130-001-00

PROBLEM: Water is a limiting factor in plant survival and production in arid and semiarid environments. Increasing the plant and animal production from rangelands in these areas requires that we manage the limited water supply in the most effective manner. One problem is the lack of basic information on the plant production as a function of water availability. There is limited information that indicates that the productivity of some plant species can be significantly enhanced with only small increases in water availability. A better understanding of plant-water relationships will assist in the development of techniques for improving the forage quantity and quality from our rangelands.

APPROACH: By collecting excess overland flow from hillsides during precipitation events and placing the water into the soil profile on lower lying areas (terraces) the water can later be utilized by plants. Also known as runoff farming or water harvesting, this technique presents an opportunity to increase forage production and, by introduction of different plant species (legumes), improve the forage quality in an area.

FINDINGS: Work was initiated in the construction of a test site consisting of level bench terraces below runoff designated areas at the Central Plains Experimental Range (CPER) near Nunn, Colorado. Since water infiltration is a major factor, techniques were developed to better field define soil properties that affect infiltration (bulk density). A rotating boom rainfall simulator was purchased that will allow the application of known quantities of water to both the runoff and runon areas.

INTERPRETATION: The field site was constructed and test procedures utilizing the rainfall simulator were developed. No data was collected on the research objectives.

FUTURE PLANS: The planned study utilizing a cool season and a warm season annual forage plant will be implemented. Plant production and forage quality under both natural rainfall and simulated rainfall will be evaluated.

STRATEGIES FOR ESTABLISHMENT OF BIG SAGEBRUSH

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CRIS: 5409-12130-001-00

PROBLEM: Wyoming big sagebrush is one of the most widely distributed and adapted shrub species in Wyoming and the region. Although considerable debate has surrounded its value, and the need for re-establishment during mined land reclamation, the fact remains that reclamationists are advised and sometimes required to restore sagebrush to mined lands at densities that approximate predisturbance conditions. Sagebrush is well adapted and persistent when mature, but establishment from seed has proven difficult. Effective strategies are needed for obtaining stands of big sagebrush on mined lands.

APPROACH: This project is composed of an "Establishment Study" and a "Pioneer Plant Study" that are being conducted simultaneously. The Establishment Study is testing the effect of mulch and perennial-grass seeding rates on the establishment and survival of sagebrush seedlings. The Pioneer Plant Study is a long-term investigation of manipulating plant succession to enhance sagebrush establishment. Both studies are also testing the effect of using fresh stripped topsoil as compared to topsoil stored for at least 5 years.

FINDINGS: The plots have been installed and seeded except for sagebrush which will be seeded in February or March 1992. A microbiological analysis was made of the topsoils. Less than a third of all soil (fresh and stripped) samples showed any mycorrhizal infection.
Thirty-three percent of yellow blossom sweetclover roots grown on fresh topsoil were infected, compared to 24% of those grown on stored topsoil. Percent infection of any one sample was generally less than 30%. Rhizobium inoculum potential (RIP) appears related to the sequence of soil replacement.

INTERPRETATION: The apparent correlation between RIP and the sequence soils were replaced may require that future comparisons be adjusted to account for this baseline difference.

SOIL ORGANIC MATTER RELATIONSHIPS IN HIGHLY ERODIBLE CROPLAND

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Rangelands Resources Research Unit

CRIS: 5409-12130-001-00

PROBLEM: A better understanding of the factors controlling soil organic matter formation and its activity is necessary to protect and restore the productivity of marginal and highly erodible cropland being reseeded to grass.

APPROACH: Field sites were established in 1987 at Egbert, Keeline, and Arvada, Wyoming. Treatments included (1) continued wheat-fallow cropping of marginal land, (2) plowed native grassland cropped to wheat-fallow, (3) reseeded grass established on long-term (<50 yrs) wheat-fallow cropland, and (4) native grassland. Soil samples were taken at 2.5 cm depth increments for the A horizon and a composite sample collected from the entire B horizon to assess changes in soil biological activities and chemical properties. Grass biomass production was also assessed on the native plots and reseeded grass plots. We continued to fertilize one-half of the reseeded grass plots in the spring with 34 kg N/ha to assess its influence on rate of carbon, nitrogen and phosphorus activity and buildup.

FINDINGS:

The 1991 soil samples exhibited a slight increase in microbial biomass, N mineralization potential, CO_2 respiration, organic carbon, kjeldahl-nitrogen and inorganic phosphorus in the surface 5 cm on the reseeded grass plots compared to the long-term wheat-fallow treatments. The fertilized reseeded grass plots generally exhibited a greater response to these parameters compared to those unfertilized plots. Even though this was true for all three locations, the poorer soils of the Egbert and Keeline sites exhibited a greater percentage increase than the more fertile clay loam soil at Arvada. The clay loam soil had exhibited the least degradation due to long-term production; probably the result of the soil texture. Clay tends to protect the soil organic matter from degradation; therefore, cropping has had a reduced effect on soil quality compared to the two sandy loam soils.

Aboveground plant biomass responded significantly to the low level of N fertilization and will probably have a significant effect on the rate of plant litter accumulation which should be reflected in the soil organic matter in future years.

INTERPRETATION: The 1991 data shows the first improvement in soil quality. This increase has occurred within the third season after grass was successfully established on the marginal croplands. It also appears that low rates of N additions, similar to that contributed by a legume, will increase the rate of change in soil quality parameters.

FUTURE PLANS: We will again evaluate soil quality and vegetation parameters at the three sites in 1992. We anticipate in 1992 to determine the effect of the treatments on this important parameter.

MANAGEMENT OF SODIC BENTONITE SPOILS

G.E. Schuman and E.M. Taylor, Jr.
Rangelands Resources Research Unit

CRIS: 5409-12130-001-00

PROBLEM: Abandoned bentonite mine spoils in the Northern Great Plains are generally saline-sodic and have a high clay content making them extremely difficult to revegetate. Sawmill wastes were incorporated into these spoils to improve their physical qualities which enhanced water infiltration and enabled revegetation. The wood residue amendment also resulted in the leaching of soluble salts from the root zone, but ESP increased due to the disproportionate amount of Na present in the system. To prevent the further degradation of the spoil quality and the potential loss of vegetation, gypsum was applied to determine its effectiveness in reducing the ESP.

APPROACH: Two studies are underway to evaluate (1) the use of surface applied gypsum to ameliorate sodicity of lands already revegetated (Study A), and (2) the use of gypsum, calcium chloride, calcium chloride + gypsum, and phosphogypsum as a spoil amendment incorporated into the spoil with wood residue before seeding (Study B). Spoil samples were taken to the 60-cm depth on both studies to evaluate the effectiveness of the inorganic amendments in correcting the sodicity problem. Vegetation biomass was also evaluated on Study B.

FINDINGS:

<u>Study A</u> - Spoil samples collected in the spring of 1991 continue to show the benefit of surface applied gypsum in reducing the ESP of the spoil. The effect of gypsum was not as pronounced in 1991 as it was in 1990 even though 1991 was significantly wetter than 1990 prior to sampling. The continued wet surface (about 35 cm) and limited infiltration might have resulted in some diffusion of salts from lower depths resulting in a sort-of equilibrium situation in May and June when it was extremely wet at the site. Spoil samples were taken in early July.

<u>Study B</u> - Spoil sodicity continues to respond to the addition of the various inorganic amendments; however, the only consistent response is that the more soluble amendments are having the greatest benefit. Aboveground biomass generally responded favorably to the amendments.

INTERPRETATION: Surface applied gypsum appears to be an effective management alternative for correcting sodicity in vegetated lands without having to disturb the soil-vegetation ecosystem.
Further evaluation of the incorporated amendments is necessary because of the short-term nature of this study to date. Therefore, spoil evaluations will be accomplished in 1992.

FUTURE PLANS:

<u>Study A</u> - No further evaluations of this study will be accomplished. This general study has been ongoing since 1981; therefore, all phases including the sodicity amelioration studies will be terminated. The last sampling for evaluation of decomposition of wood residues will be accomplished in 1993. This will represent a 10-year evaluation of decomposition.

<u>Study B</u> - Spoil and vegetation data will be collected in 1992.

GRASS: GRAZING RATES AND SYSTEMS STUDY

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Rangelands Resources Research Unit

CRIS: 5409-23610-001-00

PROBLEM: Exaggerated claims for the benefits of short-duration rotation grazing systems have received a great deal of publicity and some official recognition by SCS and other agencies. A study was begun in 1982 to evaluate the response of cattle, vegetation and soils to three grazing systems at three stocking rates.

APPROACH:

Crossbred and Hereford steers initially weighing 285 kg grazed native range 13 June-23 October 1991. Systems included continuous or season-long grazing (CG); rotationally deferred grazing in which grazing was deferred on one-fourth of each pasture until 30 August (RDG); and 8-paddock short-duration rotation grazing (SDRG). Grazing periods on the latter were adjusted according to assumed forage growth rate and forage supply, and ranged from 3 to 8 days in 1991. Stocking rates in 1991 were 29.5 (light), 52.9 (moderate) and 70.6 (heavy) steer-days/ ha. Steers were weighed every 28 days.

Peak plant biomass production was estimated inside 4 exclosures per pasture on 1 and 5 August. Biomass remaining after grazing was estimated 4 October on SDRG paddocks grazed for the last time; early and persistent snowfall prevented after-grazing measurements near the other exclosures. In August, yield was estimated on two 0.2 m2 quadrats inside each exclosure with an electronic herbage meter. One quadrat was clipped in every fourth exclosure and weighed; the regression of weight on meter readings from these quadrats was used to estimate weights on the remaining quadrats. A similar procedure was used October 4 with five quadrats outside each exclosure. Correlations of weight and meter readings (r2) in August and on October 4 were 0.91 and 0.85 respectively.

Cover of all plant species, litter and bare ground was estimated with an inclined point quadrat 10-12 July. Ten points were recorded at 50 locations along each of two transects (one on valley bottom, one on slope) in each light- and heavy-stocked pasture.

FINDINGS:

Forage production averaged 1740 kg/ha over all pastures; stocking rates and systems had no effect on production, actual or as percent of average production on the same pastures in 1982-1983. Forage production was 24% higher than in 1982-83.

Forage utilization was 40% under moderate and 70% under heavy stocking, but these means were calculated from only 4 exclosures each.

Effects of stocking rates and grazing systems on cover were:

Cover category	CG Light	CG Heavy	RDG Heavy	SDRG Heavy
	System and stocking rate			
	Cover, %			
Blue grama	2.8 b	6.0 a	7.4 a	6.0 a
Cool-season graminoids	6.2 a	3.4 b	2.8 b	3.6 b
Total plant cover*	10.1 a	11.0 a	13.5 a	10.2 a
Litter cover	79.6 a	58.2 b	63.8 b	65.2 b
Bare ground	7.2 c	24.5 a	14.9 b	17.3 b

* Excludes mosses and lichens.

Average daily gain was 0.91, 0.82 and 0.67 kg under light, moderate and heavy stocking; all differences were significant.

Under moderate and heavy stocking, grazing systems had no effect on gain; ADG was 0.76, 0.75 and 0.74 under continuous, rotationally deferred, and short-duration rotation.

INTERPRETATION: Cattle gains decreased as stocking rate increased, but systems had no effect. Neither system nor stocking rate had any effect on forage production. Heavy stocking significantly decreased litter and cool-season graminoid cover and increased blue grama cover and bare ground under all systems, but bare ground increased more under CG than RDG or SDRG. After 10 years, no beneficial effects of SDRG have been detected.

FUTURE PLANS: This study will be continued through 1993 (three complete cycles of deferment on RDG) to monitor further effects of systems and stocking rates on forage production, plant community and soil parameters (including C and N cycling if funding permits), and steer gains. Stocking rates will remain at 1990 levels.

MONITORING RANCH-SCALE TIME-CONTROLLED GRAZING SYSTEMS

Richard H. Hart
Rangelands Resources Research Unit

CRIS: 5409-23610-001-00

PROBLEM: Some producers have expressed doubts about the applicability of our grazing systems research, because pastures and paddock numbers were smaller than in most ranch-scale systems.

APPROACH: In 1990, the HR Land Co. established a 43-paddock time-controlled rotation grazing system on about 2225 ha (5500 A) of land east of Cheyenne. Joe Foster, who manages the system, invited ARS to monitor vegetation on the system. We established six 50-m cover transects in 3 paddocks of the system and placed an exclosure near each transect. Similar transects and exclosures were placed on adjacent rangeland, grazed season-long, of the Wyoming Hereford Ranch (WHR) and Buddy Hirsig's ranch (BH). Peak standing crop and cover were estimated as in GRASS above, cover on 17-18 July and standing crop on 29 July. Residual forage was estimated 4 October.

FINDINGS: Mean peak standing crop was 1660 kg/ha; correlation of meter readings with standing crop (r2) was 0.84. Bare ground averaged 14.0% on native range and 29.4% on crested wheatgrass, and litter cover was 65.9% on range and 55.4% on crested, with no differences among systems (ranches) in either measurement. Crested wheatgrass cover was 7.4% on the WHR vs. 1.2% on the HR Land Co. No differences in plant cover on native range were found among systems. Total plant cover was 16.4%; cover of blue grama was 8.2%; of western wheatgrass 0.7%; and of needle and thread 2.9%. Correlation of meter readings with residual forage (r2) was 0.85 in October. Utilization averaged 62% on native range and 84% on crested, with no differences among systems.

INTERPRETATION: Initial cover of plant species and litter and utilization levels were similar on native range on all 3 ranches in the first year. Therefore comparisons among ranches of future changes on native range should be valid. Crested wheatgrass cover differed markedly between HR and WHR; changes will be monitored in coming years, but will not be compared between ranches.

FUTURE PLANS: Monitoring will continue for several years.

MUGS: MOVEMENT, UTILIZATION AND GAINS ON SYSTEMS

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Rangelands Resources Research Unit

CRIS: 5409-23610-001-00

PROBLEM:

Improved cattle gains on ranch-scale short-duration rotation grazing systems may owe as much to improved distribution and shorter distances to water as to any beneficial effects of rotation on vegetation.

This study compared cattle gains and forage utilization on two 24-ha pastures grazed season-long (C24); a 208-ha pasture grazed season-long (C208); and a 192-ha pasture divided into eight 24-ha paddocks, grazed as a short-duration rotation system (SDRG). Additional distribution problems were created by the shape of C208 which was about 0.4 km wide and 5 km long, with the only water source at one end. Maximum distance to water was 1.0 to 1.6 km in C24 and SDRG.

Pastures were grazed June-October, 1986 through 1990, with cow-calf pairs, yearling heifers, and dry cows at approximately 1 AUM/ha. Grazing periods under SDRG were 3-10 days. Cattle were weighed every 28 days. An exclosure was placed at the end of each SDRG paddock farthest from water; each was paired with an exclosure placed just across the fence in C208. Additional exclosures were placed in the centers and near water in four SDRG paddocks, and three exclosures were distributed across each C24 pasture. Peak standing crop was estimated in late July or early August and utilization was estimated at the end of each grazing season by the same methods used under GRASS.

In 1989 and 1990, colored plastic neck chains, each a different color, were placed on six cows nursing calves in the SDRG and the C208 herds, and on 3 nursing cows in each C24 herd. Activity of each chained cow was recorded at 15-minute intervals, dawn to dark, on 4 days per treatment in 1989 and 6 days in 1990. Location was plotted on a gridded map each time activity was recorded; total movement was calculated from grid coordinates.

FINDINGS: A manuscript was prepared and is in peer review.

INTERPRETATION: In 4 of 5 years, cow and calf gains under C24 were as good as gains under SDRG, while gains under C208 usually were less. Poorer performance under C208 was associated with more grazing time and/or travel, indicating difficulty in meeting energy requirements and more energy expenditure. SDRG may have no advantage over continuous grazing other than that produced by better livestock distribution and reduced energy expenditure in travel.

FUTURE PLANS: The manuscript will be revised and published.

MODELLING PLANT AND ANIMAL RESPONSES ON RANGE

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CRIS: 5409-23610-001-00

PROBLEM: Models are needed which are simple enough to run on desk-top computers but complete enough to aid decision-making in range management.

APPROACH: SMART and STEERISK as now written are appropriate only for semi-arid rangeland with predominantly spring and summer precipitation. Weather parameters for rangeland locations throughout the US will be compiled. The SPUR II model will be used to re-parameterize SMART and the weather data will be used to develop probability distributions of forage production for STEERISK for each of these locations. Cw-calf versions of both models will be developed.

FINDINGS:

Over 300 requests for SMART have been received from researchers, action agency personnel, livestock producers, consultants, bankers, and high school and university teachers, located from New York to California, Georgia to Washington state, and in Canada, Mexico, Paraguay, Argentina, Italy, and Spain. Requests from areas where SMART is not applicable were referred to modelers at appropriate locations. The large number and geographic area of requests for SMART indicate the enormous demand for such a model.

Weather data was compiled from locations representing 46 Major Land Resource Areas (MLRA's) in which range cattle production is a major economic activity.

FUTURE PLANS: SMART and STEERISK will be parameterized for each of the 46 MLRA's. A manuscript will be prepared for presentation at the XVII International Grassland Congress in 1993 as an invited paper. An ARS bulletin will be prepared with tables of parameters for each MLRA.

CHEW: CALF HUSBANDRY AFTER EARLY WEANING
CREW: COW RESPONSE TO EARLY WEANING

Richard H. Hart and J. W. Waggoner Jr.
Rangelands Resources Research Unit

CRIS: 5409-23610-001-00

PROBLEM: Calves are usually weaned at 150 to 180 days old, in September or October. By this time amount and quality of forage is so low that weaned calves make little or no gain, and cows are slow to regain any weight lost during nursing. Research indicates 60 to 90-day-old calves are capable of using substantial amounts of forage. Post-weaning gains might be increased substantially if calves were weaned at this age, in June or July when more forage of higher quality was available, although some supplemental concentrate feed might be needed immediately after weaning.

APPROACH:

Two native range pastures were stocked at 4.4 ha/ cow-calf pair (moderate SR), and two at 3.6 ha/pair (heavy SR) from 11 June to 24 October. Each pasture contained 20 cow-calf pairs. Calves from one pasture at each SR were weaned 10 July at 51-145 days old; calves from the other pasture were weaned 10 October at 144-232 days old. Early-weaned calves were held in dry lot and fed good-quality hay for two weeks, then divided into two groups of 20 calves each, with equal numbers from each SR. These groups were assigned to 2 previously ungrazed native range pastures, 1 with 3 dry "mentor" cows and one without cows, at 0.5 ha/calf. Cows and calves were weighed about every 28 days.

Colored plastic neck chains were put on six calves in each group. Calf behavior (time spent grazing, traveling, and nursing [before weaning] and at water and salt) was observed and recorded at 15-minute intervals, dawn to dark, on 1 day before summer weaning and 2 days after summer weaning but before fall weaning.

Forage production was estimated as in GRASS, with 4 exclosures per cow-calf pasture and 3 exclosures per weaned calf pasture. Early and persistent snow prevented estimates of residual forage after grazing ended.

FINDINGS:

Forage production was 1660 kg/ha; correlation (r2) between meter readings and standing crop was 0.97.

Weaned calves spent more time grazing and less time resting than unweaned calves on 30-31 July, 20-21 days after summer weaning, but not on 4-5 September, 56-57 days after summer weaning (Table 1). Stocking rate and presence or absence of mentor cows had no effect on activity patterns. Unweaned calves nursed 0.57, 0.45, and 0.27 hr/day on 25-26 June, 30-31 July, and 4-5 September, respectively.

Date	Treatment	Grazing	Resting	Traveling
		hr/day		
25-26 June	All	5.5	8.7	1.0
30-31 July	Weaned	8.0*	6.5*	0.8
	Unweaned	7.1	7.1	0.9
4-5 Sep	All	6.0	6.0	0.7

* Time spent by weaned and unweaned calves in this activity was significantly different

Summer-weaned calves with mentor cows gained 0.24 kg/da vs. 0.20 kg/da gained by calves without cows, 24 July-8 October. The difference was significant when variance because of age at weaning was removed by covariance. Gains of calves without mentor cows were significantly ($r2 = 0.49$) and positively correlated with calf age; ADG increased 4.4 g/day of age at weaning. Gains of weaned calves with cows were not ($r2 < 0.01$). Younger calves appeared to benefit from association with mentor cows; the youngest half of the calves with cows gained 0.23 kg/da while the youngest calves without cows gained only 0.06 kg.

Under moderate stocking, fall-weaned calves gained 1.08 kg/ da from 11 June to 10 October when they were weaned. Under heavy stocking they gained significantly less, 0.99 kg/da. Heavy stocking also reduced gains of summer-weaned calves from 11 June to weaning on 10 July; 0.90 kg/da vs. 1.21 kg/da under moderate stocking. Weights of summer-weaned calves on October 8 were 141 kg without mentor cows and 149 kg with cows; initial weight on 11 June was 95 kg. Weights of fall-weaned calves on October 10 were 212 kg under moderate stocking and 210 kg under heavy stocking; initial weights were 82 and 90 kg, respectively.

Cows with fall-weaned calves gained less than cows with summer-weaned calves, and cows on heavy stocking gained less than cows on moderate stocking. Gains (kg/da) were 1.02 on summer moderate, 0.80 on summer heavy, 0.62 on fall moderate, and 0.51 on fall heavy.

INTERPRETATION: Summer weaning increases cow gains, but at great cost in calf gains. Unless compensatory gain makes up much of the loss, summer-weaned calves must be weaned later and/or supplemented after weaning.

FUTURE PLANS: These studies will be continued for several years.
Summer-weaning will be done 20-30 days later in the future. After one or two more years of summer-weaning onto native range, the effects of supplemental feeding of summer-weaned calves may be studied or weaned calf gains on native range vs. irrigated pasture may be compared.

SHAG: SUPPLEMENTING HEIFERS FOR ACCELERATED GROWTH

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Rangelands Resources Research Unit

CRIS: 5409-23610-001-00

PROBLEM: For successful calving as 2-year-olds, British-breed heifers should weigh approximately 300 kg when first bred and 400 kg at delivery of their first calf. If these weights are not achieved, first calving may be delayed, delivery may be difficult, and condition of the heifer may be so reduced that rebreeding for the second calf may be unsuccessful. All these events increase costs and reduce profits.

APPROACH:

Two native range pastures were stocked with yearling heifers at 2.6 ha/head from 12 June to 24 October. Beginning 5 July, heifers on one pasture were supplemented with free-choice high-energy blocks containing 15% crude protein. Forage production, supplement consumption, and heifer gains were determined.

Heifers were exposed to bulls at 15 months of age. Subsequent breeding and calving performance will be related to treatment and gains.

FINDINGS: Forage production was 1660 kg/ha; early and persistent snow prevented estimates of utilization. Supplement consumption averaged 0.46 kg/day. Heifers gained 0.74 kg/day without supplement and 0.73 kg/day with supplement; the difference was not significant. Mean weight on 24 October was 391 kg.

INTERPRETATION: Forage was so abundant in 1991 that heifers could make maximum gains without supplement. When supplement was supplied, it substituted for forage rather than supplementing it.

FUTURE PLANS: The study will continue for 3 to 5 years.

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GROUND WATER NITRATE

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CRIS: 5402-12130-001-00D

PROBLEM:

Managing nitrogen (N) for ground water quality is of increasing national concern, both among the general public and within the agricultural community. Important health concerns for quality drinking water in the USA must be balanced with the requirement to maintain and encourage a strong and economically viable agriculture. Central to the issue of managing N is contamination of ground water by nitrate. Nitrate, a highly mobile form of N, that can be leached through the crop root zone and eventually into ground water is a natural constituent in virtually all soils and waters and can arise from numerous sources.

The goal of any N management plan must include minimizing the leaching of nitrate from agricultural activities into ground water. Important aquifers underlie large areas of agriculturally important croplands and are estimated to supply about one-half of the supplies used in the USA. Ground water is a primary source of drinking and fresh water for both rural populations and many major cities.

APPROACH:

I have publish two books on the subject of ground water nitrates. The second book was published by the Soil Sci. Soc. Amer. (SSSA) in November and contains the NLEAP model developed by Dr. Marvin Shaffer, et al. The Soil Conservation Service (SCS) is testing the NLEAP model extensively in 3 hydrologic unit area (HUAs)/ demonstration sites strategically located across the USA. Additionally, to validate NLEAP I have obtained a data base from irrigated research plots in North Dakota that I will be testing.

Dr. Francis Pierce from Michigan State University was brought to Fort Collins by the Soil-Plant-Nutrient Research Unit to specifically work with Dr. Marvin Shaffer to complete the NLEAP model and to begin developing a Geographic Information System (GIS). GRASS-GIS procedures were developed for the Sycamore Creek Watershed in MI.

FINDINGS:

Technology to transfer information and approaches for N-management to Action Agencies are a highly important part of implementing research results nationally. Training sessions on N management principals and the SSSA book edited by Dr. Follett have been given at 3 of the 4 National Technical Centers of SCS and will be given at the 4th in March. Personnel trained include SCS State-office personnel from all 50 States and Extension Service and Environmental Protection Agency Personnel from all four regions.

The procedures developed during Dr. Pierce's sabbatical should be transferrable to any other watershed in the United States with suitable database availability. In addition, the procedures used should allow other point models (besides NLEAP) to be used with the GIS shell that is being designed. The approach used provides for knowledge of the spatial occurrence of nitrate leaching in agricultural systems to be

used to manage N for crop productivity and ground water quality. The spatial distribution of various nitrate leaching indices were predicted using NLEAP for continuous corn under recommended N fertilizer management in combination with spatial data contained in a GIS. This analysis delineated potential nitrate leaching 'hotspots' within the Sycamore Creek Watershed in MI. The linkage between NLEAP and GIS provides a new tool for eventually targeting current water quality initiatives at a national level.

DRYLAND CROPPING SYSTEMS

Ronald F. Follett
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CRIS: 5402-12130-001-00D

PROBLEM: It is projected that between 60 and 70 percent of all US cropland will be farmed with some type of conservation tillage by the year 2000. Tillage systems influence soil properties, N-use efficiency, and nitrate leaching. Consequences of widespread adoption of reduced-tillage practices on Great Plains soils is not adequately understood. Also not adequately understood are the consequences of long-term tillage on N-use efficiency and nitrate leaching in the Great Plains.

APPROACH:

A no-till dryland cropping rotation study was initiated at Akron, CO four years ago to determine N-pool sizes and seasonal or annual rates of movement of N between and out of various pools available for plant uptake. The approach was: (1) to utilize ^{15}N isotope to study uptake of fertilizer-N versus soil N into growing crops, (2) to utilize isotopically labeled crop residues to study crop residue N movement into the subsequent crop(s), into microbial biomass, and/or active versus stabilized soil-N pools, and (3) to measure the movement of ^{15}N isotope from organic matter and fertilizer pools into a leachable mineral pool that has moved below the bottom of the crop root zone.

The last four years have been used for data collection at the Akron site. Much of the analyses for the first four years is either completed or is being done; the plan is to now go into a longer-term observation phase. Samples were collected at boot, heading and mature growth stages and are being analyzed for ^{15}N, total N, and dry matter accumulation. During 1990, we began looking at the residual N uptake and utilization from previously applied normal abundance KNO_3-N and KNO_3-^{15}N fertilizer. The cropping sequence was wheat-sorghum-fallow-wheat rotation.

FINDINGS: Because of the cost of N-15 isotope to conduct field experiments, part of the above study was designed to determine minimum microplot size for unbordered plots. This approach allows normal field operations to be used. Our results indicate that for no-till dryland wheat, the minimum microplot size with fall-applied ^{15}N is 1.5 by 1.5m. 1988 and 1989 grain yields for wheat and sorghum ranged from 2830 to 3030 and 2270 to 4165 kg/ha, respectively. Additional results indicate N-fertilizer use efficiencies of 39 to 46% for wheat and 49 to 57% for sorghum. An efficiency of fertilizer N being recycled from the wheat straw to the subsequent sorghum crop that was grown in 1989 ranged from about 8 to 9%. Microbial biomass C from 1988 to 1990 has ranged from about 200 to nearly 500 mg/kg soil and has increased with time, likely as a result of decreased time in fallow with a wheat- sorghum-fallow rotation vs. the previous wheat-fallow rotation that the field had been in. Through 1990, there appears to be no difference in microbial biomass C levels among N-fertilization rates.

CATION CONCENTRATION RELATIONSHIPS IN PLANT TISSUE

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-001-00D

PROBLEM: The sucrose content of sugarbeet is reported to have generally decreased in the US since the early 1950's. Sucrose extraction (quality) is affected by the presence of potassium (K), sodium (Na), and a number of non-sucrose constituents. The role of major monovalent cations, K and Na, on sucrose recovery has been extensively researched. However, the role of major divalent cations, Calcium (Ca) and Magnesium (Mg), has been much less extensively studied. The purpose of this study was to evaluate the effect of variety and nitrogen (N) fertilization on sucrose dry matter, and cation concentrations in sugarbeet root.

APPROACH: Chemical analyses data were collected for sugarbeet root tissue, grown in a factorial experimental design with three N rates and two varieties randomized in each of four replications.

FINDINGS:

The concentration of divalent cations (meq weight basis) varied much less during the growing season than did the more mobile monovalent cations, but were still responsive to especially varietal differences. Therefore, their concentration in sugarbeet roots may be useful for comparison to the concentration of monovalent cations. When compared, a good correlation of the monovalent:divalent cation ratio to the dry-matter content found in sugarbeet roots was observed. If for no other reason, having a high dry-matter content per unit of sucrose is important because such a sugarbeet characteristic minimizes the need to haul excessive amounts of water weight from the field to the factory. This study further showed that dry-matter content of sugarbeet roots is strongly influenced by variety and N-fertilization. A high percentage of water weight in fresh sugarbeet roots dilutes both the dry matter and the sucrose contained in them. Higher level of sugarbeet water-content (lower dry matter) observed for the hybrid variety and the higher N-fertilizer treatments was highly associated with increased concentration of monovalent cations in dry root material.

Monovalent and divalent cations provide most of the internal ionic balance with anions contained within the plant. The anions involved undoubtedly include many that are detrimental to purity of factory juices and are non-sucrose constituents that decrease sucrose crystallization. Non-sucrose constituents likely include anions such as carbonate, chloride, amino acids, betaine, glutamic- and other organic-acids, and sulfate. It is very likely that sum of cations (i.e. Na plus K plus Ca plus Mg), expressed on a milliequivalent weight basis, is related to the concentration of a number of non-sucrose impurities contained in sugarbeet roots. Therefore, not only the percent sucrose, but also juice purity might be expected to increase as the sum of cations decreases.

CHLOROPHYLL METER TO EVALUATE N-STATUS OF WINTER WHEAT

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-001-00D

PROBLEM:

Spring application of part, or perhaps all, of the fertilizer-N applied to dryland winter wheat (Triticum aestivum L.) in the western Great Plains region may offer advantages to applying fall only N-application. A major advantage to spring-N application is that it allows evaluation of stand and stored soil moisture to be made first. An additional advantage is that of a shorter period of capital tie-up with spring N application compared to fall application. Research conducted in Colorado shows spring-applied N is equal, and in some cases superior, to fall application for increasing winter-wheat grain yield and protein content. These results indicate dryland wheat producers can use either fall- or spring-timing to apply fertilizer-N.

Use of soil and leaf tissue testing for determining crop N deficiency is widely accepted in the Great Plains. Soil samples taken to a depth of 60 cm have been used to develop a spring N fertilizer recommendation model. Likewise, fertilizer-N recommendations can be made with leaf tissue-N tests at the plant growth stage of Feekes 5. The primary problem with spring soil- or leaf tissue-tests is the time required for sampling, laboratory analysis and interpretation, and fertilizer-N recommendations by a farm advisor to the producer. Turnaround time for this service must be very fast or it will be too late to make a profitable spring fertilizer-N application.

APPROACH:

Four existing replicated N rate studies in Colorado were used to compare yield, leaf N concentration, soil tests and SPAD 502 chlorophyll meter readings of dryland winter wheat. The four sites

are designated as Akron 1, Akron 2, Punkin Center, and Willard. The N fertilizer treatments for the Akron 1 location were 0, 28, 56, 84 and 112 kg ha^{-1}. The N fertilizer treatments for the Akron 2 location were 0, 34 and 68 kg ha^{-1}. The Punkin Center and Willard studies both had N fertilizer treatments of 0, 22, 44 and 68 kg ha^{-1}. The wheat cultivar TAM 107 was planted at all locations.

Readings were taken using a SPAD-502 chlorophyll meter at mid-length on the uppermost fully expanded leaf from approximately 20 randomly selected plants. Readings were avoided that would be directly on the leaf midrib. The leaf was removed from the plant by detachment at the leaf collar to facilitate ease of taking chlorophyll meter readings. The leaf was then saved for determination of leaf N concentration. The wheat plants were sampled on April 17 to 19 at approximately Feekes 5 Growth Stage. Nitrogen concentrations of leaf tissue were determined by automated combustion analysis. Soil samples for NH_4-N and NO_3-N analysis were taken from each plot at the same time leaf samples were removed for meter readings and leaf N analysis. Soil samples (air dried) were analyzed for available NO_3-N and NH_4-N by a Technicon Autoanalyzer.

FINDINGS: In general, calibration of the SPAD-502 chlorophyll meter against yield, leaf N or available soil N (NH_4-N + NO_3-N) is possible. However, factors such as location, cultural practices, moisture availability, soil profile N and cultivars' differences may have an effect on leaf greeness and the resulting chlorophyll meter readings. In the current study a grain yield response might be expected for a meter reading of less than about 42. However, a significant yield response was observed at the Willard site with a meter reading of 50 compared to meter reading of 48 or less. Because a chlorophyll meter provides a unitless indication of leaf greeness, utilization of this technology may require normalizing the data relative to an adequately fertilized area of the field.

AMMONIA EMISSION FROM SOYBEAN RESIDUE DECOMPOSITION

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-001-00D

PROBLEM:

Ammonia (NH_3) may be the most important of the nitrogen (N) gases exchanging with the earth's surface in N-budget measurements between earth and atmosphere. Decay of crop residues is a major source of the N that potentially contributes to exchange of NH_3 between cropland soils and the atmosphere. When crop residues, especially legumes, are returned to the land as green manure, even larger amounts of NH_3 per unit of land area would be expected to evolve. In the United States, about 3,000 Gg of N are returned to cropland soil in crop residues each year; of which soybean residues alone account for about 23 percent.

Currently, there are few studies of NH_3 evolution from the decay of crop residues. The relative importance and interactions of factors affecting decomposition of crop residues and their contributions to NH_3 exchange to the atmosphere are likely quite complex. Our objective was to assess the importance of soil temperature, soil moisture, and crop residue addition rates on NH_3 losses from soybean residue amended soil.

APPROACH: Soil was a Weld silt loam. Soybean tissue and soil were mixed to obtain 5 or 2.5% by weight plant tissue to soil mixtures in pots. Individually each pot was placed in a desiccator and wet to either 100 or 60% of field capacity (FC) moisture levels for Experiment I with an additional treatment of 20% of FC for Experiment II. In Experiment I Coker soybean tissue was incubated single 7d incubation period during which time no air flowed across the soil surface; the incubation was followed immediately with a 4d dry-down period during which moisture- and NH_3-free air was passed across the soil surface at a constant flow rate. Ammonia liberated from the soybean:soil mixture was collected during the dry-down period. In Experiment II Tracy soybean tissue was used for four repeated wet-dry cycles, each consisting of a 7d incubation period followed by a 7d dry- collection period, and then rewetting to the original moisture treatment before the next cycle. Liberated NH_3 was trapped in 0.1M HCl in boats. All experiments were conducted in a constant temperature room.

FINDINGS: We found gaseous NH_3 losses from soybean:soil mixtures were highly associated with evaporative loss of water from the soil. More NH_3 is volatilized at FC than at 60 or 20% FC. We also found more NH_3 volatilized at 30°C than at 20°C or 10°C, and more at the 150g soybean rate than at the 75g soybean rate. This N loss is significant with four cycle repetition giving over 5% N loss for a 30°C, FC, 150g soybean tissue run. Since an estimated 3000 Gg of N are returned to cropland soils in soybean residues annually, then even a 5% loss is appreciable, and losses are likely much higher. Since our soybean tissue was obtained from tops after harvest, a greener manure would be expected to produce an even greater N loss. Analysis of the oven-dry soil following the incubation dry-down period showed significantly higher levels of NH_4-N at higher moisture level. This observation is consistent with data in Experiment II showing apparent increased rates of mineralization at higher moisture level. We found that volatilized NH_3 from soybean-residue amended soil showed fractionation between ^{14}N and ^{15}N isotopes with the leading fraction lower in atom% ^{15}N than the trailing fraction. The fractionation parallels trends observed in steam distillation of NH_3, diffusion of NH_3, and NH_3 volatilization from senescing wheat.

ROLE OF THE PLANT HORMONE ETHYLENE IN SYMBIOTIC NITROGEN FIXATION

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CRIS: 5402-12130-002-00D

PROBLEM:

The overall objective of this research program is to develop biotechnological methods to enhance the agricultural use of biological nitrogen fixation. Current research has examined the role of ethylene in this process. Ethylene, while simple in structure, is a powerful natural regulating substance that exerts a major influence on many aspects of plant growth and development. It is produced in plants by the following biosynthetic pathway: methionine → *S*-adenosylmethionine → 1-aminocyclopropane-1-carboxylic acid (ACC) → ethylene. Many of the effects that IAA has on plant processes such as growth, root induction, epinasty, flower induction and geotropism are now attributed to auxin-induced ethylene production. Ethylene production by vegetative tissues may be naturally regulated by the internal levels of auxins.

There is limited evidence that ethylene may regulate nodulation. 1) Ethylene inhibits nodulation in some legumes. In *Phaseolus vulgaris* nodulation was decreased 90% on explants exposed to 0.4 ppm ethylene. Whole *Pisum sativum* and *Trifolium repens* plants treated with ethylene had both fewer nodules and less nitrogen fixation than untreated control plants. 2) Nodulated *Medicago sativa* produces more ethylene than do non-nodulated plants 3) Nodulated or nitrogen sufficient legumes may produce sufficient ethylene to interfere with their own nodulation. In enclosed cultures, endogenously produced ethylene interfered with the nodulation process and reduced the nitrogen fixing ability of existing nodules on *T. subterraneum*. Also, *Medicago sativa* plants that produce 6.0 to 7.1 pmoles of ethylene plant $^{-1}$ h^{-1} were observed to form 5.1 nodules plant $^{-1}$. But, nodulation increased to 11.4 nodules plant $^{-1}$ when ethylene production was decreased to 2.1 - 2.9 pmoles plant $^{-1}$ h^{-1} by the addition of aminoethoxyvinylglycine. Aminoethoxyvinylglycine prevents ethylene biosynthesis by blocking the conversion of *S*-adenosylmethionine to ACC.

APPROACH: The general objective of the present study has been to increase our understanding of the role ethylene plays in the soybean-*Bradyrhizobium* association. Specific objectives were as follows: 1) Do nodulated soybean root produce more ethylene than non-nodulated roots? 2) Are the nodules a major source of this ethylene? 3) Does the nitrogen nutrition of the plant influence the production of ethylene by the root? 4) Does the ethylene produced by nodulated soybeans interfere with nodule formation or function?

FINDINGS: Initial studies were conducted with four week old hydroponically grown soybean plants. Root ethylene production was measured using a open flow-through system that allowed ethylene produced by the root system to be trapped without disturbing the plant. These studies demonstrated that the presence of nodules on the root does result in an increased production of ethylene by the root system. Inoculated plants were found to produce nine times more ethylene than control plants that were not inoculated (Table 1). A portion of the increase in ethylene production may be due to the improved nitrogen nutrition of nodulated plants. Nitrogen starved soybeans produce less ethylene than do plants that receive sufficient nitrogen (Table 2) and this may account for a portion of the ethylene produced by nodulated plants as nitrogen fixed by the nodule would improve the nitrogen nutrition of the plant.

Table 1. Effect of nodules on ethylene production by soybean root.

Treatment	Ethylene produced (pmol g fresh sw^{-1})
Uninoculated	5.3
Inoculated	48

Table 2. Effect of nitrate supply on ethylene production by uninoculated soybean plants.

Nitrate supplied (μmol)	Ethylene produced (pmol g^{-1} f. wt h^{-1})
None	6.4±0.8
412	6.0±0.6
825	6.9±1.2
1650	11.8±2.4
2500	19.4±4.2

Do nodules produce ethylene? Two studies have been conducted. One involved the use of a closed system for the estimation of ethylene production. For this study roots, stripped of their nodules, were placed in one sealed container, the nodules were placed in a second container and the amount of ethylene produced by each measured. The results suggest that nodules produce almost twice the ethylene per gram fresh weight as do roots (Table 3). These results were confirmed by a second study. In plant systems ACC is the immediate precursor of ethylene and changes in tissue ACC content often parallel increases in ethylene production. Thus the amount of ethylene produced by a plant structure can be estimated from the amount of ACC present. Studies with root and nodule material show that nodules contain considerably more ACC (and thus would be expected to produce more ethylene) than do roots (Table 4). High levels of ACC were also detected in nodules from plants inoculated with the ineffective 5MT-7 strain. This high level of ACC would not be expected if the increase was due to improved nitrogen nutrition. The 5MT-7 strain nodulates but the nodules formed are low in leghemoglobin content and fix almost no nitrogen. Past studies have shown that the nitrogen nutrition of plants inoculated with the 5MT-7 strain resemble the uninoculated control.

Table 3. Closed system ethylene production by detached nodules and denodulated root.

Plant structure	Inoculum	Ethylene produced (pmol g^{-1} f. wt h^{-1})
Nodule	Wildtype	184±38
Nodule	5MT-7	199±33
Root	Wildtype	103±23
Root	5MT-7	95±27

It is the plant rather than the bacterial portion of the nodule that is responsible for the production of ethylene within the nodule. Nodules were fractionated into their component parts (bacteroid, cytosol, and cell debris) using differential centrifugation and a portion of each incubated in a sealed flask. The results show that about 98% of the ethylene produced by the nodule components came from the two plant fractions. Only very small amounts of ethylene were associated with the bacteroid fractions (Table 5).

Table 4. ACC content of roots and nodules from plants inoculated with an effective inoculum (wild type) and an ineffective inoculum (5MT-7).

Treatment	Plant structure	ACC (nmol g. fresh wt.$^{-1}$)
No inoculum	Root	0.44±0.08
Effective inoculum	Denodulated root	0.58±0.10
"	Root with nodules	0.98±0.07
"	Nodules	1.90±0.15
Ineffective inoculum	Denodulated root	0.33±0.06
"	Root with nodules	0.44±0.06
"	Nodules	1.52±0.05

INTERPRETATION: The results demonstrate that nodulated soybean roots produce more ethylene than do uninoculated roots. Part of this increase is due to the improved nitrogen nutrition of the nodulated plants and part due to the production of ethylene by the nodule. It is the plant portion of the nodule and

not the bacterial portion of the nodule that is responsible for ethylene production by the nodule. These results support the hypothesis that ethylene may serve as an autoregulatory signal compound, and as such, help to control the number and perhaps the location of nodules that form on the host legume root system.

Table 5. Ethyline production by nodule components.

Nodule component	Ethylene produced (nmol h^{-1})	Percent of total (%)
Bacteroid	0.1	2
Cytosol	1.9	46
Plant cell	2.1	51

FUTURE PLANS:

It is planned that CY-92 research will continue the ethylene research initiated in CY-91. Initial studies will look at the interactive effects of ethylene and nitrogen nutrition on nodulation. Preliminary CY-92 studies suggest that ethylene may not function in the same manner in the B*radyrhizobium*-soybean system as in the *Rhizobium*-legume system.

Also planned are genetic studies on the tryptophan metabolism of a supernodulating *B. japonicum* that was obtained several years ago. It is suspected that the supernodulating characteristic of this *Bradyrhizobium* is due to a genetic change in the tryptophan operon of this bacteria. However, the nature of the change has never been identified. Collaborative studies are planned that are directed at identifying the genetic change that is responsible for the supernodulating characteristic of this inoculant bacteria.

SOIL NO, N_2O, AND CH_4 EXCHANGE DURING N TRANSFORMATIONS IN SOIL

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CRIS: 5402-11000-004-00D

PROBLEM: There is increasing public and scientific concern regarding not only the prospect for global climate change, but also additional potential health and environmental effects of changing atmospheric trace gas concentrations. Gaseous N oxides, N_2O and NO_x ($NO + NO_2$), are directly or indirectly involved in "greenhouse warming" as well as the production and consumption of important atmospheric oxidants (e.g., ozone, hydroxyl) and the photochemical formation of nitric acid, which is the fastest growing component of acidic deposition. Methane is another radiatively-active trace gas with rapidly increasing atmospheric concentration; like NO_2, it is removed from the atmosphere principally via oxidation by hydroxyl, so NO_x and CH_4 compete with each other and with other pollutants for limited atmospheric oxidant. In addition to the important impacts of these gases on the chemistry of the atmosphere, soil NO_x exchange apparently comprises a sizable fraction of the unaccounted N losses typically observed in soil N balance sheets and also serves, like NH_3, as an agent for the transport and redistribution of N both within and among natural and agricultural ecosystems. Because microbial processes in soil is one of the principal sources of atmospheric N oxides, and represents both a source and sink for atmospheric CH_4, then it becomes important to determine the exchange rates of these gases across the soil-atmosphere boundary and, if appropriate, to develop control technologies (e.g., substitute land use schemes, alternative soil management practices, improved fertilizer formulations and application techniques, etc.).

APPROACH: During the last decade numerous measurements of soil N_2O emissions have enhanced understanding of the factors controlling this process and of the importance of soil emissions compared to other sources of this gas. My research focuses instead on NO_x exchange by soils and plants, for which relatively few measurements have been made, and investigates recently-advanced hypotheses concerning the relation of soil N transformation rates to CH_4 production and consumption in soil. Overall objectives of the research are (1) to characterize both the magnitude and direction of soil and foliar gaseous NO_x exchange in a variety of agronomically- and environmentally-important situations, (2) to determine the relation of NO_x to N_2O and CH_4 exchange rates in each situation, (3) to identify and characterize important controllers of the biotic an abiotic processes responsible for these exchanges, and (4) to assess the importance of the exchanges to crop productivity, to N use efficiency, to various environmental issues, and to the long-term behavior of natural and other low-N ecosystems. Procedures for laboratory soil incubation studies conducted to examine processes and pathways were summarized in a recent publication (Hutchinson and Andre, 1989). Methods for monitoring NO_x, N_2O, and CH_4 exchange at selected field sites and for field testing of preliminary laboratory findings have been summarized in previous reports.

FINDINGS: Much of the past year was consumed by the following activities not directly related to my current research program:

(1) Training of a new biological science technician, who reported 30 December 1990.

(2) Preparation of three comprehensive review articles. The first (Pub. #5) was an invited analysis of chamber systems' use for measuring trace gas fluxes from soil presented at a SSSA special symposium

(see Pub. #2), and the second (Pub. #3) summarized recent advances in our understanding of the controllers of NO and N_2O production, consumption, and transport in soil at both cellular and field/landscape scales. Probably most significant was Pub. #4, because of its completeness (110 pages), and because it represents a successful melding of biologists' and atmospheric chemists' viewpoints, which turned out to be a nontrivial undertaking.

(3) Summarization and publication of the last three years' results from cooperative studies with Prairie View A&M University (funded by NASA and a Specific Cooperative Agreement using ARS money earmarked for cooperative research at HBCU's). Two of these articles (Pub. #6 and #7) are "in press", draft copies of two more (Pub. #9 and #10) are circulating among the authors, and Pub. #11 remains to be written. Publication #8, which summarizes the other five, has been submitted for inclusion in the book recording proceedings of the international conference where it was presented (see Pub. #1).

(4) Summarization and publication of cooperative studies with Dr. W.D. Guenzi conducted in the last year preceding his 1991 retirement. ARS peer reviews of Pub. #12 have been returned, and comments are being incorporated; preparation of Pub. #13 is in progress.

Despite heavy commitment to these training and writing activities, I was able to complete planned preliminary investigations to determine the feasibility of a more comprehensive field study of relations among soil NO, N_2O, and CH_4 exchange rates to be conducted in cooperation with personnel at the U.S. Central Great Plains Research Station on the Conservation Reserve Program (CRP) conversion plots located there. The rationale and planned approach to this research are summarized in the next section of this report. Briefly, this year's results showed that (1) soil emission of NO far exceeded that of N_2O on long-term grass plots, as well as wheat plots under both no-till and conventional tillage management; (2) soil management and tillage practices had substantial influence on N oxide evolution, with emission of both NO and N_2O varying in the order grass plots > no-till plots > conventional tillage plots, (3) short-term nitrifier activity measured in fresh soil samples appeared to integrate the dependence of NO (but not N_2O) emissions on soil temperature and water content, and (4) the soil's NO emission rate appeared to covary with its CH_4 uptake rate, suggesting that chemoautotrophic nitrifying microorganisms responsible for NO production in this soil may also contribute to its CH_4 sink strength. The last result should be considered especially tentative because of the marginal sensitivity and precision of our CH_4 analytical protocol, which have since been improved. In addition, we completed laboratory measurements to determine the dependence on relative humidity of the efficiency of the chromium trioxide convertor used to oxidize NO to NO_2 prior to its analysis using a luminol-based detector; these data will be included in Pub. #14.

FUTURE PLANS:

Short-term soil emission of NO_x (usually >90% NO) has recently been measured from several different ecosystem types under a variety of soil and climatic conditions around the world. Conspicuously absent from the literature, however, are comprehensive longer-term studies that yield tenable estimates of total annual NO evolution from any particular site. Further extrapolating existing data to assess the overall contribution of soil NO emissions to the global atmospheric NO_x budget is also confounded by the apparent existence of multiple biotic and abiotic sources of the gas. For example, elevated NO emission rates are sometimes associated with very wet or waterlogged soils and are stimulated by addition of NO_3^-, indicating that the source of NO is denitrification, but in drier situations NO emissions apparently arise primarily from chemoautotrophic nitrification, which is subject to an entirely different set of controllers. Because NO and N_2O are produced by the same microbial processes, there may exist a relationship between their evolution rates from soil that would permit using the extensive database of N_2O emission measurements to forecast NO emissions at similar sites, but the paucity of simultaneous field

measurements of the two gas emission rates precludes describing any such relationship. Recent data suggest that the soil N transformations responsible for NO and N_2O production may also influence soils' rate of CH_4 uptake, but the relative contributions of specific microbial processes remain to be determined.

To overcome these limitations of existing data, we propose to (1) estimate total annual NO, N_2O, and CH_4 exchange from N-fertilized and unfertilized grass, no-till, and conventionally-tilled CRP plots at the Akron field station, (2) determine the relative contributions of nitrification, denitrification, and other processes (if they prove significant) to the measured exchange rates and (3) develop a process-level model that describes the contributions of each process to the measured exchange of NO, N_2O, and CH_4 in terms of easily-measured biological and geochemical parameters that have potential as predictors of the emission rates at other cultivated and grassland sites. Unlike existing models that attempt (with limited success) to account for the large variability in soil C and N exchange over short distance and time scales, the focus of our modeling effort will be to develop a simple equation that facilitates assessing the spatially and temporally integrated contributions of various ecosystem types, climatic regions, soil groups, and/or management schemes to regional- and global-scale budgets of the three gases by integrating soil, climate, and land use parameters in a way that reflects only the differences in annual emission rates among sampling sites. In addition to the foregoing field effort, I will complete the writing activities outlined in the previous section, and William H. Anthony and I have planned laboratory soil incubation studies to determine the effect of oxygen availability on the relative contributions of nitrification and denitrification to soil NO, N_2O, and CH_4 exchange. The latter research will serve as Mr. Anthony's M.S. thesis in accordance with the terms of Specific Cooperative Agreement No. 58-5402-1-102.

COATED CALCIUM CARBIDE AS A NITRIFICATION INHIBITOR IN UPLAND AND FLOODED SOILS

Arvin R. Mosier & Kevin F. Bronson
Soil-Plant-Nutrient Research Unit

CRIS: 0500-00026-016-00D
5402-11000-004-00D

PROBLEM: Efficient use of N fertilizers is minimized in many agricultural systems because of the loss of large amounts of the applied N through leaching of nitrate, by ammonia volatilization or by denitrification. As most fertilizers are applied to soil using ammonium (urea, anhydrous ammonia, or ammonium salts) limiting ammonium oxidation (nitrification) seems a mechanism to directly limit N loss, thereby increasing fertilizer N use efficiency. A number of nitrification inhibitors have been used but all of them are not useful in one way or another. The need remains to find a nitrification inhibitor that functions over a broad range of soil conditions, both aerobic and flooded soils, that is easily prepared, is easy to use and is inexpensive. Dr. N.K. Banerjee, recently retired from the Indian Agricultural Research Institute, New Delhi, India and I have developed a nitrification inhibitor, coated calcium carbide (CCC) that may fill the void. The initial tests on the inhibitor, presented in the 1987 Annual Report, and field studies conducted 1988-1990 indicated that the inhibitor has potential. We have conducted field studies to test the effectiveness of the material in Cuttack and New Delhi, India, Griffith, Australia and Crowley, Louisiana and have conducted further studies in winter wheat and cotton in Australia, and corn in Ft. Collins. In 1991 we conducted field studies in winter wheat in Ft. Collins, and in rice in Louisiana and Australia.

APPROACH: The field experiments were set us as described in earlier, 1988-1990 annual reports. Using CCC as a slow release source of acetylene exposes soil microorganisms to acetylene continuously for several months. As it is not known if such long term exposures create deleterious side effects, Dr. Leif Klemedtsson, visiting post doctoral fellow from Sweden initiated a project to determine the effect of long term exposure of acetylene on nitrification, denitrification and microbial biomass.

FINDINGS: No yield response was observed in the Crowley, LA rice CCC trials in 1991, indicating that coating technology needs to be perfected. Both the dry seeded rice and winter wheat studies in Australia and Fort Collins, respectively, show that CCC effectively slowed nitrification.

FUTURE PLANS: The field studies have shown that CCC has great promise as a nitrification inhibitor, but coating technology needs to be perfected. We are currently working with Dr. B.G. Byrnes of the International Fertilizer Development Center, Muscle Shoals, Alabama to develop new coating procedures. A funding proposal is being prepared to try to obtain funds from EPA to develop new coating procedures at IFDC and for field testing by Louisiana State University and the International Rice Research Institute in the Philippines. Concluding measurements will be made in August, 1992 to complete the studies of long term exposure of soils to acetylene.

TRACE GASES AND GLOBAL CLIMATE CHANGE

Arvin R. Mosier & Kevin F. Bronson
Soil-Plant-Nutrient Research Unit

CRIS: 0500-00026-016-00D
5402-11000-004-00D

PROBLEM: It is generally agreed that if present trends for the emission of greenhouse gases (CO_2, CH_4, N_2O and chlorofluorohydrocarbons) from the earth's surface into the atmosphere continue, mean global temperature will rise two to six °C during the next century. Such a global atmosphere temperature increase would cause a rise in the ocean's water level, possibly change precipitation patterns, and alter agricultural production. According to discussions during a recent International Conference on "Soils and the Greenhouse Effect" the relative importance of agriculture and land use to the production of CO_2, CH_4, and N_2O were 30, 70, and 90 % respectively. The chlorofluorocarbons are derived industrially. One recommendation from this conference is that intensive studies be made about conditions leading to the formation and escape of CO_2, CH_4, and N_2O in and from the soil with the aim of creating the necessary scientific basis for improved land management practices.

APPROACH:

A. A field program was begun in 1990 to monitor N_2O and CH_4 flux in a variety of grassland agroecosystems over a 3 to 5 year period. See the 1990 annual report for methodology. These monitoring programs have continued and are expanding to include other sites in the Great Plains, managed grasslands and subalpine meadows. New field studies were also begun to separate gas diffusion from biological oxidation to show which processes control CH_4 uptake under specific soil conditions.

B. Field studies were conducted to determine the effect of nitrification inhibitors on N_2O emissions from fertilized wheat and rice fields.

C. To expand the scope of soils available to our studies we are developing an ARS network of sites, starting with Dr. Verlan Cochran's study sites in Alaska; the Fort Collins sites and yet to be identified sites in Puerto Rico.

D. Development of process level, regional models for CH_4 and N_2O is beginning. Drs. Bill Parton and Dennis Ojima, Natural Resource Ecology Laboratory, Colo. St. Univ., are conducting the modeling effort.

FINDINGS:

A. The patterns observed in the 1990 field flux studies persisted throughout 1991. The data continue to show that N fertilization and cultivation of native soils decreases CH_4 uptake thus contributing to increasing atmospheric concentration of CH_4.

B. We conducted field studies in irrigated winter wheat and dry seeded rice to determine the impact of CCC and commercially available nitrification inhibitors on N_2O emissions from urea-fertilized soils. Both CCC and dicycandiamide decreased N_2O emissions about 50% during a 290 d period. In dry seeded rice,

during the four weeks between seeding and fertilization and permanent flooding, CCC decreased N_2O emissions 73% while nitrapyrin increased N_2O production by 23% relative to soils treated with urea alone (Table 1).

C. Data collection has been proceeding since 1990 in the Colorado portion of the Alaska-Colorado-Puerto Rico trace gas network. Field studies will begin in Alaska with the snow melt and efforts are now underway to set up a program in Puerto Rico. The effort in Puerto Rico will involve the USDA/Forest Service as well as the ARS lab. in Mayaguez.

D. The modeling effort is just beginning. Data from all of our earlier N_2O flux studies are being assembled and incorporated into the data set that began in 1990.

FUTURE PLANS:

A. The gas flux monitoring and mechanistic studies concerning CH_4 and N_2O will continue. Depending upon funding level, three proposals written jointly with Colo. St. Univ. cooperators and a Kansas St. Univ. cooperator are pending. If new funding is available the sampling network will be expanded across the Great Plains.

B. Inhibitor studies are continuing with cooperators in Australia.

C. We will continue coordinating the Alaska-Colorado-Puerto Rico Network with Dr. Verlan Cochran and a yet to be identified post doctoral research associate.

D. As soon as the soil thaws to permit the studies, Dr. David Valentine, a DOE funded post doctoral fellow, will begin studies to differentiate between gas diffusion and microbial consumption and production of CH_4 and N_2O. These data will be used directly in the development of equations to describe the flux of these gases.

TRACE GAS FLUX IN MANAGED GRASSLANDS

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-11000-004-06S

PROBLEM: Other studies from northeastern Colorado grasslands indicate that cultural practices and N-fertilization alter both N_2O and CH_4 fluxes. A unique grassland is the managed mountain meadow system which is irrigated and generally heavily N-fertilized. Because of the general management scheme in such grasslands it seems likely that fluxes of N_2O from the system would be large and the flux into the system small, relative to other less intensely managed systems. On going research at the Colorado State University Beef Research Center, near Saratoga, Wyoming provides an opportune research site. Dr. Hunter Follett of the CSU Agronomy Department has an established research site where he has been conducting fertilizer trials for several years. He has agreed to maintain those trials for the next three years to accommodate our studies.

APPROACH: Plots within Dr. Follett's experimental area have been established where N-fertilizer is applied at either 0, 40 or 80 kg N ha^{-1} either in the spring or autumn. The flux of N_2O and CH_4 will be monitored at selected intervals to determine the effect of N-fertilization and irrigation management on the flux of these gases.

FINDINGS: Initial gas flux measurements were made at selected times July-October, 1991. The influence of usual cultural practices in the system appear to influence the flux of both N_2O and CH_4. Dr. Follett applied the autumn fertilizer application in September, 1991. The spring fertilizer application will be made when snow conditions permit and gas flux studies will begin at that time. Funding for this project was released in September, 1991.

MEASUREMENT OF NITROUS OXIDE AND METHANE IN NATIVE AND MANAGED GRASSLANDS FOR DEVELOPMENT OF PROCESS BASED GAS FLUX MODELS

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-11000-004-05S

PROBLEM: Appropriate models which can be used to predict how the atmospheric exchange of trace gases with soil are influenced by the physical, chemical and biological conditions of soils. The flux of N_2O and CH_4 is being measured in a variety of agricultural and native systems and concomitant physical and biological measurements are being made. Dr. Bill Parton and coworkers at the Colorado State University, Natural Resource Ecology Laboratory will use these data to develop process, based models to permit prediction of both N_2O and CH_4 fluxes on local and regional basis.

APPROACH: Currently, data from experiments we have conducted during the past 12 years are being assembled in to use in model development. When the data is organized into a usable package then equations will be derived to describe the relationship between gas fluxes observed from the field measurements, the physical, chemical and biological parameters measured in the field at the same time that the gas flux measurements were made and the processes which drive gas flux. The intent is to develop models which describe gas fluxes both on the local and regional scales.

RESULTS: Funding for this project was released in September, 1991. Data organization and assembly into usable computer format was begun in October and continues. More than 10 years of field data available to use in this model development along with the new data that is being acquired daily.

Table 1. Effect of nitrification inhibitors on N_2O emission from urea-fertilized, cropped fields.

Treatment	Mean N_2O Flux Rate (g N ha^{-1} d^{-1}) — Crop		
	Maize[1]	Rice[2]	Wheat
Control	1.1^a	38^a	2.1^a
Control + CCC	4.1^a	14^b	1.8^a
Urea	31^b	73^c	5.8^b
Urea + DCD	_[3]	–	2.5^a
Urea + NP	16^b	99^d	–
Urea + CCC	5.4^a	16^b	2.3^a

[1]Numbers in each column followed by the same letter are not significantly different (p=0.05).

[2]The gas flux measurement period over which mean rates are calculated was 97 d (n=140) for maize, 23 d (n = 33) for rice, and 292 d (n=240) for wheat.

[3]A dash indicates no measurement made.

GROUND WATER NITRATE

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-001-00D

PROBLEM:

Major national concern continues over the potentially harmful environmental impacts associated with excessive agricultural nitrogen (N) losses into groundwater. Groundwater protection from non-point contamination of nitrate from agricultural activities is considered essential. Agricultural production and concerns for economic viability of the agricultural community are linked to N. This is because available soil N supplies are generally inadequate to supply this major plant nutrient for optimum crop growth and additional fertilizer N must be supplied to maximize production. The majority of N fertilizers are applied as anhydrous ammonia, ammonium salts or urea and all are rapidly converted biologically to nitrate. Nitrate is highly soluble and mobile and moves with the soil water in the crop root zone. Nitrates not used by the crop during a growing season have the potential to move below the root zone and eventually into groundwater.

Various crop management systems (sprinkler irrigated corn, minimum till rotations, etc.) are use in the Great Plains. Fertilizer nitrogen management and research in these systems must focus on increasing fertilizer N efficiency (plant utilization) while minimizing the leaching or movement of nitrates below the root zone.

APPROACH:

Efforts have been directed at publishing a long-term depleted ^{15}N study. This eight year study was concerned with long-term N-use efficiency, and nitrate movement and leakage beneath the root zone as affected by adequate and excessive fertilizer rates and various rates of irrigation water in three years of continuous corn. And then recovery of the residual soil profile nitrates over years with continuous dryland winter wheat. All yield and N analyses have been completed. Statistical analyses have been completed for all parameters but the nitrate distribution in soil profiles. The data has been presented at the annual meeting of the American Geophysical Union and the Great Plains Soil Fertility Conference. Since the results have been present in previous annual progress reports I will not present any findings or interpretations.

FUTURE PLANS:

I am now in the final stages of writing several journal articles.
and hope to finish them shortly.

Statistical approaches to the soil nitrate profile data need to be discussed with Dr. Richardson. Whether we will be able to do anything but plot nitrate concentrations with soil depth has to be determined.

DRYLAND ROTATION SYSTEM

Lynn K. Porter
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CRIS: 5402-12130-001-00D

PROBLEM:

The use of minimum tillage and rotation systems are rapidly changing how the Great Plains is farmed. Minimum tillage or conservation tillage where stubble and residues remain on the soil surface influence the amount of moisture entering and stored in soil profile thus permitting more frequent cropping, usually in dryland areas a wheat-sorghum-fallow or a wheat-corn-fallow system. The affects of such management systems on N efficiency and nitrate leaching, and soil organic matter turnover are unknown.

APPROACH: A cooperative dryland, minimum-till, wheat-sorghum-fallow rotation with two rates of ^{15}N-nitrate fertilization was initiated at Akron, CO in 1988. This long-term cooperative study with Ron Follett and Ardell Halvorson has as it objectives to determine: 1) uptake or assimilation of fertilizer N verses soil N by wheat and sorghum using tagged nitrate fertilizer as affected by N rates, year or years of application, and residue management. 2) minimum ^{15}N microplot size for accurately measuring ^{15}N uptake for wheat and to determine if border of microplot is maintained over time with minimum tillage operations. 3) the movement of ^{15}N isotope from organic matter and fertilizer N pools into potentially leachable mineral pool, i.e. how does the soil profile nitrates (tagged and non-tagged) respond to management (fertilizer rate, number of fertilizer applications and wheat straw exchanges, crops and fallow). 4) the incorporation of the tagged N into microbial biomass (readily mineralizable pool) versus stabilized soil organic pools as affected by management. 5) the residual effects of prior fertilization rates and cropping on wheat N utilization and yield when no fertilizer is applied. 6) how 'added nitrogen interactions' (ANI) vary with management, i.e how rate and sequence of applying tagged fertilizer affect the recover of tagged and soil nitrogen.

FINDINGS AND INTERPRETATION: Winter wheat without any applied fertilizer was grown during the 1990-1991 cropping season. The effects of residual N applied during the wheat-sorghum-fallow rotation is reflected in this year's total above ground crop (wheat) yields of 1308, 1474, and 1911 kg/ha for the N rates of 0, 50 and 100 lbs N/acre respectively. The total above ground crop (wheat) yield for the 1988 crop was 6797, 6504 and 7096 kg/ha for the 0, 50 and 100 lbs N/acre respectively. The wheat crop yield following sorghum and fallow without any more fertilization yielded only about one third the 1988 crop. Part of this effect may be weather related.

FUTURE PLANS: This year the microplots will be fertilized with a non-tagged ammonium source N fertilizer and planted to a grain crop. We will then harvest at various growth stages across the microplots to check the integrity of the ^{15}N microplot boundaries after 4 years. Fertilizing with non-tagged N should allows us to determine the effects of prior tagged fertilizer N treatments on the 'Added N Interactions".

ISOLATION, CHARACTERIZATION AND GROWTH HABITS OF CELLULOYTIC-N_2 FIXING MICROORGANISMS: (EXPLORATORY)

Lynn K. Porter
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-01S

PROBLEM: Cellulose is the most abundant polysaccharide produced in nature with an annual production of about $0.75*10^{11}$ tons. Cellulose products are the major trash item entering U.S. municipal landfills. It has long been thought that cellulose degradation occurred separately from biological N_2 fixation. However, recent discoveries raise the possibility that celluloytic-N_2 fixing organisms might be widely distributed in nature. Depending upon their abundance and distribution such organisms could exert a significant influence on carbon and nitrogen cycling in various ecosystems. Moreover, if such organisms could be cultured in the right environments it is possible that cellulose wastes and residues could be turned into useful products. Hopefully this research would provide society with another avenue for disposal of trash cellulose. Current projections are that landfill tipping fees will exceed $100/ton within this decade and that the amounts of cellulosic wastes to be disposed of will rise to near 100 million tons/yr. Objectives of the study are to isolate cellulolytic microorganisms, determine if they can fix N_2 and to what extent and try to outline optimum cultural requirements.

APPROACH: Cellulose enrichment cultures devoid of N will be used to isolate aerobic, anaerobic, and microaerophilic cellulolytic microorganisms. Such organisms would be cultured and their N_2 fixing ability tested by acetylene reduction and $^{15}N_2$ incorporation. Those organisms showing considerable N_2-N fixing ability would be studied to determine the optimum nutritional and environmental conditions need for their growth.

FINDINGS: Supplies and nutrients have been ordered and received and work has just begun. Postdoctoral Research Associate funding has been obtained.

FUTURE PLANS: A major effort will be made to find a postdoctoral microbiologist who can push this effort forward. In the mean time we will begin to take samples and start enrichment cultures.

EFFICIENT USE OF FERTILIZER AND SOIL NITROGEN

Lynn K. Porter
Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-01S
SCA 58-5402-9-013

PROBLEM: Spit Root Studies. Means for improving N use efficiency as well as preventing nitrate leaching and denitrification losses is need. Encapsulated calcium carbide inhibits nitrification which in turn prevent denitrification and the formation of nitrates. Limited information indicates that calcium carbide may improve crop yields. Additional studies are needed to determine how calcium carbide performs under field conditions. Tagged N is used to measure the amount of fertilizer N uptake (N use efficiency) and the amount of fertilizer N moving as nitrates. One of the shortcomings of the isotopic method is the stimulating effect of the added fertilizer N on the uptake and mineralization of indigencus soil organic N. Ammonium source fertilizers exhibit the greatest 'added N interaction (ANI)'. Many mechanisms have been proposed as explanations for this phenomenon and probably several are involved. Usually the ANI is positive which causes the uptake of the fertilizer N to be lower than expected, especially when uptake of N is compared the non-isotopic 'difference method'. This phenomenon complicates the interpretation of ^{15}N uptake data and needs study. Whether plants tissues come to an isotopic equilibrium at various growth stages was explored this year using split root corn plants.

APPROACH:

Field test of the coated calcium carbide (CCC) were conducted in drill-seeded flooded rice at the Louisiana Rice Research Station, Crowley, LA during 1991.

A split root approach with the same top soil in both portions of the split was utilized. In some of the pots enriched ^{15}N was applied to one side and depleted ^{15}N on the other the split. In control pots the enriched and depleted N sources were mixed and then applied equally to both proportions of the soil. The corn was separated at harvested into roots, stalks and leaves numbered from the bottom of the plant to the top. Each tissue sample was analyzed for total N and ^{15}N.

FINDING AND INTERPRETATIONS:

Adding CCC with urea before permanent flooding provided a 17% yield increase compared to urea alone in 1990. Whereas in 1991 the yield showed no affect due to CCC. These tests, along with other crops, shows that CCC is an efficient nitrification inhibitor but in order to obtain reproducible results a reproducible coating technology needs to be developed.

In the split root studies, equal fertilization of all the soil used resulted in fairly uniform split root growth. As in prior studies the split roots never came to an isotopic equilibrium. For example, approximately one month after seeding, the roots in one of pots where the depleted and enriched source had been mixed before application the Atom % ^{15}N for the 2 roots samples was 2.18 and 2.23 whereas, for the 2 root samples from a pot where the isotopes were kept separate Atom % ^{15}N was 1.08 and 3.39. A plant harvested 75 days after seeding showed an Atom % ^{15}N for the an Atom % ^{15}N for mixed before application of 2.13 and 2.10 and for a plant where the isotope enrichment was separated of 1.83 and 2.49. The data indicate there was translocation of the enriched ^{15}N into the depleted ^{15}N side of the split root but at no time during the growth of these corn plants did they attain isotopic equilibrium. The leaf

data also indicates that younger leaves have a different isotope enrichment than older leaves. This means that harvesting just one leaf will not reflect the isotope abundance of the plant, that the entire plant must be harvest and uniformly ground to give a homogeneous sample. Secondly, banding isotopes in greenhouse pot and field studies will result in tissues (especially root) that have a different isotope content.

FUTURE PLANS: Further work is needed producing reproducible coatings on calcium carbide. The effort on ANI this year will be mainly on publishing the results thus far obtained. However, the work mentioned above for the rotation study does involve ANI.

THE EFFECT OF CULTIVATION ON THE ASSOCIATION OF ORGANIC MATTER WITH SOIL AGGREGATES

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Soil-Plant-Nutrient Research Unit

CRIS: 5402-12130-002-00D

PROBLEM: It is well established that soil organic matter levels tend to decrease with cultivation, and that losses of organic C and N are correlated with decreases in soil structure and increases in erodibility. Soil organic matter consists of fractions with varying degrees of decomposability. However, little is known about the nature of the association of various organic matter fractions with soil aggregates, nor is it well understood how this association influences organic matter decomposition. A better understanding of the association of organic matter with soil aggregates, and how cropping affects this association, will enable us to better quantify, predict, and differentiate the effects of cultivation and erosion on long-term soil productivity.

APPROACH: In 1987, a long-term cooperative study was developed with G.E. Schuman and R.A. Bowman to evaluate changes due to cultivation in physical, chemical and biological properties of Central Plains soils. Field plots were established at three locations along temperature and soil texture gradients, but with similar annual precipitation. Each site consists of marginal cropland that has been cropped for over 50 years, and undisturbed native grasslands in close proximity. Treatments include (1) continued grain-fallow cropping, (2) continued native grassland, (3) plowed native grassland subjected to grain-fallow cropping, and (4) reestablished grassland on marginal cropland. Soil properties analyzed annually or seasonally include: organic and mineral N, P and C concentrations of the bulk soil (G.E. Schuman and R.A. Bowman); microbial biomass (G.E. Schuman); soil texture, pH and bulk density (G.E. Schuman); aggregate size distribution (J.D. Reeder); and organic and mineral N, P and C concentrations of soil aggregate size fractions (J.D. Reeder and R.A. Bowman).

FINDINGS AND INTERPRETATION: A manuscript reporting the development of a modified anaerobic incubation procedure for measuring mineralizable N was written and submitted for review. Compared to the standard anaerobic incubation procedure, this modified procedure significantly reduces coefficients of variation by eliminating transfer errors, and reduces analysis and processing time by one third. A manuscript reporting the effects of long-term cropping on bulk soil physical and nutrient properties is currently in preparation.

FUTURE PLANS: In 1992, the manuscript reporting the modified anaerobic incubation procedure will be defended as a Master's Thesis in February, and submitted for publication to SSSAJ in March. The manuscript reporting long-term cropping effects on bulk soil properties will be submitted for publication, and a second manuscript reporting long-term cropping effects on soil aggregate properties will be drafted. Additional samples will be collected from the field plots and analyses will continue.

SUGARBEET RESEARCH UNIT

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VARIETAL SUSCEPTIBILITY OF NEMATODE TRAP CROPS TO *RHIZOCTONIA SOLANI* FROM SUGARBEET

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CRIS: 5402-21220-002-00D

PROBLEM: Oil mustard (*Sinapis alba*), radish (*Raphanus sativus*), and buckwheat (*Fagopyrum esculentum*) are grown extensively in Europe as trap crops for the sugarbeet cyst nematode (*Heterodera schachtii*). Trap-crop roots are invaded by the nematode, but nematode reproduction is altered so that few females are formed. Previously, we have shown that selected cultivars of mustard and radish were susceptible to several sugarbeet fungal pathogens, with greatest susceptibility exhibited toward the seedling disease and root-rot strains of *Rhizoctonia solani*. Because certain nematicides may be banned in the near future, great interest in these trap crops has developed in the U.S. for biocontrol of the cyst nematode. Use of these crops in areas where Rhizoctonia diseases are prevalent may necessitate the development of genetic resistance to the pathogen. Preliminary to initiating a breeding program, we need to determine which cultivars of the trap crops, if any, exhibit resistance to *R. solani*.

APPROACH: Seven radish, four mustard, and two buckwheat cultivars were planted in steam-pasteurized soil infested with *R. solani* (damping-off isolate R-6 or root-rot isolate R-9). A randomized complete block design was used, with five replications and 40 seeds per cultivar per replication. Controls were seed of each cultivar and sugarbeet planted in noninfested soil. Seedling survival as a percentage of control survival was recorded 21 days postplanting.

FINDINGS: In soil infested with R-6, radish cultivar Siletina, mustard cultivar 3-9002, and buckwheat cultivar Tardo had the highest survival (Table 1). In soil infested with R-9, radish cultivar Fortissimo, mustard cultivar 3-9002, and buckwheat cultivar Tardo had the highest survival. All trap crops exhibited greater survival than sugarbeet regardless of pathogen strain.

INTERPRETATION: The obvious interaction of fungal isolate X cultivar indicates that selection or breeding for resistance to the two pathogen strains will have to be conducted independently in different trap crop types. However, because the strains that induce damping-off (e.g., R-6) are controlled effectively with available seed-treatment fungicides, initial selection and breeding efforts would best be conducted against the sugarbeet root-rot strains (e.g., R-9). The variability in susceptibility of the trap crops indicates that initial mass selection for resistance should result in an increase in resistance.

FUTURE PLANS: A second trial will be conducted in 1992 and data will be subjected to analyses of variance. The most resistant cultivars then will be used for initial mass selections to increase resistance levels.

Table 1. Survival of trap crops planted in soil infested with two strains of *Rhizoctonia solani* (R-6 & R-9) as a percentage of control survival planted in noninfested soil; means of five replicates

Cultivar	Type	% of control survival R-6	% of control survival R-9
Pegletta	Radish	44	21
Nemex	Radish	38	13
Siletina	Radish	71	32
Adagio	Radish	41	19
Siletta Nova	Radish	54	44
Salubre	Radish	40	27
Fortissimo	Radish	34	63
Metex	Mustard	33	42
Maxi	Mustard	14	18
3-9001	Mustard	21	53
3-9002	Mustard	35	78
Prego	Buckwheat	85	36
Tardo	Buckwheat	91	52
MonoHy D-2	Sugarbeet	9	8

EFFECT OF NEMATODE TRAP-CROP GROWTH ON SOIL POPULATION DENSITIES OF *RHIZOCTONIA SOLANI*

Earl G. Ruppel
Sugarbeet Research Unit

CRIS: 5402-21220-002-00D

PROBLEM: Although nematode trap crops may be more resistant to *Rhizoctonia solani* than sugarbeet, growth of these species may affect the population density of this soilborne fungal pathogen, thereby contributing to the epidemiology of Rhizoctonia diseases in subsequent sugarbeet crops.

APPROACH: Seeds of three mustards (*Sinapis alba*), one radish (*Raphanus sativus*), and one Rhizoctonia-susceptible sugarbeet were planted in 6-inch pots of steamed, pasteurized soil infested with a very low population density of either isolate R-6 (damping-off strain) or R-9 (root-rot strain) of *R. solani*. Plants grown in noninfested soil served as controls. A randomized complete block design was used in each of two trials, with four replications per trial. Seedling survival was recorded 30 days postplanting as a percentage of control survival, percent damping-off was calculated, and soil of each pot was assayed for *Rhizoctonia* by means of a special soil-pellet sampler and a *Rhizoctonia*-selective medium.

FINDINGS: Growth of the trap crops and sugarbeet increased the soil population density of isolate R-6 97-98% and that of isolate R-9 by 93-98% in the 30-day period (Table 2). Soil population densities of both isolates were highest in soil in which radish cultivar Nemex had grown, yet seedling death also was lowest in these soils. Seedling death was not correlated with population densities of either fungus isolate.

INTERPRETATION: Because seedling death was not correlated with final population density of the pathogen strains, it appears that genetic influences of the trap crops are more important than population densities of the pathogen in regard to damping-off. The great increases in population densities of the pathogen strains indicates that, regardless of their level of resistance to *R. solani*, they nevertheless can serve to build up primary inoculum of the pathogen for subsequent sugarbeet crops.

FUTURE PLANS: Trap-crop debris infected with *R. solani* will be tested for pathogen survival in soil under various storage conditions.

Table 2. Damping-off of nematode trap crops and sugarbeet and soil population densities of *Rhizoctonia solani* isolates R-6 (damping-off strain) and R-9 (root-rot strain) following 30-days growth of the crops in steam-pasteurized soil containing the pathogens at initial densities of 0.05 propagules per gram of soil

	Propagules/g soil		% Damping-off	
Cultivar[a]	R-6	R-9	R-6	R-9
3-9001 (M)	2.0	1.2	15.0	52.5
3-9002 (M)	1.9	0.7	22.5	60.0
Maxi (M)	2.4	1.0	17.5	52.5
Nemex (R)	3.0	2.0	5.0	40.0
FC 901 (SB)	2.0	1.3	80.0	95.0

[a]M = mustard; R = radish; SB = sugarbeet.

EFFECT OF RHIZOCTONIA ROOT ROT ON YIELD OF SUGARBEET CULTIVARS WITH VARIED DEGREES OF RESISTANCE - THIRD YEAR'S RESULTS

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CRIS: 5402-21220-002-00D

PROBLEM: Concern among sugarbeet breeders and sugar producers that there may be some loss of root or sucrose yields in hybrids developed with resistance to *Rhizoctonia solani* led an experiment to resolve this question. Thus, a test was conducted in 1989 and repeated in 1990 and 1991. We report herein the results of our 1991 trial; results of previous tests were reported in our 1989 and 1990 Annual Progress Reports.

APPROACH: Five sugarbeet entries, having Rhizoctonia resistance levels from susceptible to highly resistant, were planted in the field and inoculated with root-rot isolate R-9 of *R. solani*. The experiment was a 5 X 3 factorial arranged in a randomized complete block design with four replicates. Plots were four rows wide and 6-m long. One third of the plots were inoculated 60 days postplanting, another third at 70 days postplanting, and the final third were not inoculated. In early October, roots in the two center rows of each plot were lifted, rated for root rot on an increasing disease scale of 0 to 7, topped, washed, weighed, and analyzed for sucrose and thin-juice purity. Data for all parameters were subjected to analyses of variance and regression and correlation analyses. Percent data were transformed to arcsine-square roots for analyses.

FINDINGS: Disease indices (DI) and root yield are given in Table 3; DIs are compared with % sucrose, recoverable sucrose, and % sucrose in Table 4. As in previous trials, early inoculation induced more root rot and decreased yields more than the late inoculation. There was a direct relationship between disease severity and yield parameters for the susceptible HM 55 and the moderately resistant HH 32. Reduction in root yield, percent sucrose, and recoverable sucrose were not as great in ACH 184, FC 709, or the experimental three-way hybrid (FC505/FC708//FC712), the latter having two genomes from resistant pollinators, as compared with HM 55 or HH 32.

Table 3. Disease indices (DI) and root yield at harvest of five sugarbeet cultivars inoculated with *Rhizoctonia solani* 60 or 70 days postplanting in the field

	DI[b]			Root yield (t/ha)[b]		
Entry[a]	1	2	CK	1	2	Ck
HM 55	6.4	4.5	0.8	5.2	23.9	47.7
HH 32	5.2	4.0	0.5	13.8	34.0	46.3
ACH 184	4.0	2.6	0.5	33.2	44.4	43.4
FC505/FC708//FC712	3.1	1.4	0.5	38.8	42.5	44.5
FC 709	1.6	1.1	0.5	36.6	35.0	35.8

[a]HM 55 = susceptible commercial hybrid; HH 32 and ACH 184 = moderately resistant commercial hybrids; FC505/FC708//FC712 = resistant experimental hybrid; FC 709 = resistant breeding line.

[b]1 = inoculated 60 days postplanting; 2 = inoculated 70 days postplanting; CK = uninoculated check.

Table 4. Disease indices (DI) and % sucrose, recoverable sucrose (t/ha), and % sucrose at harvest of five sugarbeet cultivars inoculated with *Rhizoctonia solani* 60 or 70 days postplanting in the field

Entry[a]	DI[b]			Sucrose (%)[b]			Recoverable sucrose[b] (t/ha)			Purity[b] (%)		
	1	2	CK	1	2	CK	1	2	CK	1	2	CK
HM 55	6.4	4.5	0.8	5.2	8.5	16.1	0.3	1.5	6.6	81.8	85.6	93.2
HH 32	5.2	4.0	0.5	6.7	9.2	16.7	0.7	2.3	6.8	85.9	84.1	94.1
ACH 184	4.0	2.6	0.5	11.8	13.4	17.5	2.8	4.9	6.7	86.7	91.2	94.4
FC505/FC708//FC712	3.1	1.4	0.5	13.2	15.0	15.9	4.0	5.4	6.0	88.2	92.0	92.6
FC 709	1.6	1.1	0.5	13.5	14.8	15.7	4.1	4.3	4.8	91.8	92.0	92.7

[a]See footnote for Table 3.

[b]See footnote for Table 3.

FUTURE PLANS: Additional statistical analyses of data and publication.

POTENTIAL OF *STREPTOMYCES GRISEOVIRIDIS* AS A BIOCONTROL AGENT OF SOILBORNE SUGARBEET FUNGAL PATHOGENS

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CRIS: 5402-21220-002-00D

PROBLEM: Except for a few seed-treatment fungicides to control damping-off of sugarbeet by *Pythium* spp. and AG-4 strains of *Rhizoctonia solani*, fungicides have not been registered for the control of mature-beet root rots. Even if efficacious chemicals were registered for this use, biological control offers a safer and more natural means of suppressing disease-causing pathogens.

APPROACH: In vitro inhibition. A dehydrated, commercial preparation of *Streptomyces griseoviridis* was rehydrated and then cultured on malt-extract agar. Sugarbeet pathogens *Aphanomyces cochlioides, Botrytis cinerea, Fusarium avenaceum, F. oxysporum, Phoma betae, Pythium aphanidermatum, P. ultimum, Rhizoctonia solani* (isolates R-6 and R-9), and *Sclerotium rolfsii* plus another biocontrol agent (*Trichoderma harzianum*) were grown on potato-dextrose agar (PDA). Each test fungus was co-plated with *S. griseoviridis* on PDA. At 6 days after plating, inhibition zones between *S. griseoviridis* and the test fungi were measured. A completely randomized design was used with five replicates in each of two trials.

FINDINGS: Clear zones of inhibition were evident between *S. griseoviridis* and all sugarbeet pathogens except *Sclerotium rolfsii* (Table 5). Although *S. rolfsii* hyphal growth was not inhibited and this fungus grew over the biocontrol agent, sclerotial formation of *S. rolfsii* was inhibited or delayed in close proximity to the agent growth. An inhibition zone also was evident between *S. griseoviridis* and *T. harzianum*.

Table 5. In vitro growth inhibition of several sugarbeet fungal pathogens and another biocontrol agent (*Trichoderma harzianum*) in dual culture on potato-dextrose agar

Sugarbeet pathogen	Inhibition zone (mm) in test 1	2	Mean
Aphanomyces cochlioides	3.6	5.4	4.5
Botrytis cinerea	14.8	14.4	14.6
Fusarium avenaceum	11.2	9.4	10.3
F. oxysporum	12.4	12.2	12.3
Phoma betae	13.4	8.4	10.9
Pythium aphanidermatum	0.8	3.0	1.9
P. ultimum	2.0	4.2	3.1
Rhizoctonia solani (R-6)	11.0	12.8	11.9
R. solani (R-9)	7.6	11.2	9.4
Sclerotium rolfsii[a]	0	0	0
Trichoderma harzianum	4.0	5.0	4.5

[a]No zones of inhibition; however, sclerotial formation was inhibited in close proximity to *S. griseoviridis*.

INTERPRETATION: The bacterium *Streptomyces griseoviridis* has potential as a biocontrol agent of several soilborne sugarbeet fungal pathogens. The formation of clear, hyphal-free zones indicates that the mechanism of inhibition is antibiosis rather than parasitism of the pathogens by the agent. The slight, but definite, inhibition of another biocontrol agent, *Trichoderma harzianum*, is disturbing, because this agent has shown potential for biocontrol of *Pythium* spp. and *R. solani*.

FUTURE PLANS: *Streptomyces griseoviridis* will be tested for its potential control of Fusarium yellows (*F. avenaceum* and *F. oxysporum*) and Rhizoctonia damping-off in soil culture. The agent also will be tested for control of storage-rot of sugarbeet caused by *Botrytis cinerea* and *Phoma betae*.

COMBINING ABILITY TEST OF RHIZOCTONIA RESISTANT POLLINATORS

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CRIS: 5402-21220-002-00D

PROBLEM: To be valuable to sugarbeet breeders, germplasms (pollinators) developed for resistance to *Rhizoctonia solani* in our program should combine well with female parents used in hybrids. Good combining ability assures breeders that hybrids produced with our germplasms will be good yielders.

APPROACH: A limited combining ability test was conducted on four *Rhizoctonia*-resistant pollinators in a disease-free field at Fort Collins. Four sets of hybrids were tested with four pollinators in a randomized complete block design with six replications. Two commercial hybrids were included for comparative checks.

FINDINGS: There were significant differences for sucrose among the four sets of hybrids (Table 6). FC 702-7 was the pollinator of the hybrid set with the highest sucrose content (15.5%), but its set had the lowest average root yield (18.9 kg/21-ft single-row plot). Some of the individual hybrids within the sets of hybrids were equal to the checks.

Table 6. Means of groups of *Rhizoctonia*-tolerant test hybrids with common pollinators

Pollinator of the set of hybrids + two checks	Sucrose (%)	Plot wt (kg/plot)	Gross sucrose (kg/plot)
FC 707-2	14.7	19.7	2.90
FC 702-7	15.5	18.9	2.93
FC 712	14.5	19.8	2.87
FC 709	15.0	19.2	2.88
Rhizoctonia-susceptible check (HM 1605)	16.0	20.0	3.20
Rhizoctonia-tolerant check (HM RH1)	14.6	21.2	3.10
$LSD_{(0.05)}$	0.8	3.1	NA

INTERPRETATION: Combining ability (CA) was relatively good for the four pollinators used in this test. One pollinator (FC 702-7) showed better CA for percent sucrose than the other pollinators, but the other pollinators tended to be better combiners for root yield, although differences in means among all groups were not significant.

FUTURE PLANS: Future plans will depend on the research geneticist being recruited to replace Hecker.

GERMPLASM DEVELOPMENTS FOR RESISTANCE TO RHIZOCTONIA ROOT ROT

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CRIS: 5402-21220-002-00D

PROBLEM: *Rhizoctonia solani* induces a serious root rot of mature sugarbeet in most production areas. No chemicals are registered for control of this disease, and cultural control measures are not adequate by themselves. Increased levels of genetic resistance are needed to minimize growers' losses from this disease.

APPROACH: Genetic information developed previously in our research was used to execute additional cycles of pathogen inoculation, plant selection, and recombination among germplasms that we have in our cyclic improvement program. Germplasms in various stages of improvement were evaluated for resistance in inoculated field tests. Results of these tests were the basis of decisions about specific germplasms, i.e., retain, shelve, discard, recombine, release, register, etc. Germplasms likely to be useful for variety improvement were identified and released for use by other sugarbeet breeders.

FINDINGS: The most resistant sugarbeet germplasms developed in this project are not immune, but they had up to 97% harvestable roots in the 1991 inoculated field test. We believe this level of resistance expressed in a severe inoculated field test should be sufficient to provide adequate protection in most indigenous *Rhizoctonia*-invested fields. However, all the genes for resistance in these germplasms would need to be present on both homologous chromosomes in commercial hybrids if the same level of resistance is to be expected. In 1992, approximately 12 germplasms will be released to sugarbeet breeders based on our 1991 and previous years' tests.

FUTURE PLANS: Future plans will be formulated after the successful replacement of Hecker. Some breeding lines in various stages of development for Rhizoctonia resistance will be tested in our 1992 field nursery, and seed of other lines will be increased in preparation for their release at a later date.

IN VITRO POLLEN TECHNOLOGY TO ASSAY AND SELECT FOR ECONOMIC CHARACTERS IN SUGARBEET

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CRIS: 5402-21220-002-00D

PROBLEM: Traditional genetic enhancement and breeding techniques for characters in sugarbeet are limited in extent and speed of making genetic improvements. New technology is needed to provide more positive genetic identification, selection, and combination into useful genetic backgrounds.

APPROACH: For several years, we tested sugarbeet pollen as a suitable tissue for challenge and selection for Rhizoctonia root rot and Cercospora leaf spot resistance, tolerance to high and low temperature, salinity, and heavy metal (aluminum) toxicity, as well as detection of hybrid vigor and germplasm preservation. In the past year, we completed projects involving tolerance to extreme temperatures, selection for aluminum tolerance, and the relation of pollen vigor to pollen germination. We also initiated and completed a project involving the improvement of pollen germination by fractionation. In cooperation with plant physiologist Susan Martin, we developed techniques to analyze pollen sugars and attempted to correlate sucrose levels in pollen with those of parental sugarbeet lines.

FINDINGS: In our study involving the chilling injury of pollen, the hypothesis was that pollen that functioned best at low temperature would effect the most fertilization, and that this functional superiority would be expressed in progeny that grew faster at low temperature. After five cycles of cold challenge of pollen and fertilization, resultant progeny did not develop faster in the cold than did the controls. A similar study was initiated to challenge pollen that would function at high temperatures and possibly produce progeny that would grow faster in hot climates. Seedlings from the first cycle of selection were compared with control seedlings in their ability to withstand high temperatures. There were no significant differences in radicle length or percent seed germination of selected seed as compared with controls. Challenge and selection of pollen for aluminum tolerance was completed through the second cycle for two lines of sugarbeet. Pollen germination and germ tube length were no better in selected lines compared with controls in a medium with higher aluminum concentrations after one or two cycles of selection. Pollen vigor (germination in 1 hr) was compared with pollen germination (24 hr) for sugarbeets and various B. maritima lines. Vigor, germination, and the ratio of the two was higher for pollen of B. maritima than for sugarbeet. In our HPLC analysis of sugarbeet, kind and quantity of sugars in pollen were established. Quantity of sucrose in pollen was not correlated with sucrose content in roots of the same line. A method of pollen fractionation employing the physical separation of viable and nonviable portions was developed. It could potentially increase pollen germination when large quantities of pollen are available.

INTERPRETATION: New breeding technology research, with pollen as a tissue to manipulate and test, has made some progress, namely, cryogenic long-term storage of beet pollen and evidence of genetic change toward increased salinity tolerance. Pollen may be a useful tissue for study of certain characteristics, but it is apparent that techniques must be precise. In challenging and selecting pollen, we were unable to effect significant change in the genetic control for ability to tolerate extreme environmental conditions.

FUTURE PLANS: Our unit will continue research to introgress Rhizoctonia resistance genes into commercially useful backgrounds. However, evaluation of pollen as an in vitro tissue for genetic assay and selection is of limited usefulness. Although no further pollen work is planned, our traditional approach will be supplemented by technologies from our or other labs.

BIOCHEMISTRY OF THE SUGARBEET ROOT SURFACE AND ITS RELATIONSHIP TO PROCESSING QUALITY

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CRIS: 5402-21220-002-00D

PROBLEM: There is need to develop new technology to decrease non-sucrose impurities detrimental to the processing of sugarbeets. Specifically, there is insufficient knowledge of the distribution within the sugarbeet root, or change in concentration with time, of major "impurities." This information is necessary in order to make an economic assessment of the feasibility of peeling as a means of improving processing quality and sucrose recovery.

APPROACH: A previous experiment in which sugarbeets were stored under nearly ideal conditions and analyzed at 0, 8, 16, and 24 weeks of storage showed that significant changes occurred within the first sampling period (8 weeks of storage). To explore these biochemical changes, in CY 91, we made similar analyses of chemical constituents in the sugarbeet root and peel at 0, 2, 4, 6, and 8 weeks of high-quality storage. Four cultivars were tested. In addition, with the cooperation of a sugarbeet processing company, we placed samples of the same varieties into an actual factory storage pile for 8 weeks. During this storage test in the outdoor, air-ventilated factory pile, weather conditions provided an environment that can be considered typical of good to excellent factory pile storage.

FINDINGS:

A. High-Quality Storage under Defined Conditions. Sucrose in whole roots declined by 11% in 8 weeks of storage at 4C and near-100% RH, whereas there was a 29% decrease in peel sucrose during that time. Whole-root concentrations of raffinose and "invert sugar" (glucose plus fructose) increased significantly after just 2 weeks of storage. Extractable concentrations (% of root fresh weight) of invert continued to increase with time in storage, but raffinose levels declined back to at-harvest concentrations (Fig. 1). At every sampling period, peel concentrations of raffinose and invert sugar (expressed per unit of sucrose present) were about 3.5- and 14-fold, respectively, the whole root levels (Fig. 2). Concentration changes through 8 weeks of storage were negligible for sodium, potassium, amino-acid nitrogen, and the organic base betaine.

B. Samples Stored in a Factory Storage Pile. Expressed as percent of root fresh weight, the sucrose concentration of samples stored 8 weeks in the factory pile increased relative to the concentration at harvest. This was due to root dehydration; however, on a dry weight basis, sucrose declined 0.55% in pile samples relative to at-harvest levels. The sucrose decline in pile samples was less than the 2.13% decline observed in samples stored at 4C for 8 weeks.

Extractable raffinose and invert sugar levels of pile-stored samples increased 62% and 136%, respectively, above at-harvest levels; pile samples contained less raffinose but more than twice the invert sugar of samples stored a comparable time under controlled temperature (Fig. 1; Cf. above).

Peel levels of raffinose per unit sucrose, compared to whole-root levels, were similar in pile-stored samples and high-quality controlled storage samples; in contrast, peel to whole root invert ratios in pile samples were significantly lower than those under controlled storage (Fig. 2), because whole-root invert levels in pile samples were much greater than in samples from controlled storage. Sodium, potassium, amino-acid nitrogen, and betaine levels in pile-stored samples were essentially unchanged from at-harvest samples or those stored 8 weeks under controlled temperature.

INTERPRETATION: Significant biochemical changes occurred within 2 weeks in samples harvested, transported, and washed by hand, which would have resulted in minimal injury (much less than would result from commercial harvesting, transporting, and piling practices). These changes may result from the inevitable wounding and physiological disruption that occurs at harvest. After a short burst of accumulation at 2 weeks after harvest, raffinose levels declined and remained at levels comparable to harvest, whereas monosaccharides (glucose and fructose, the breakdown products of sucrose, collectively called "invert sugar") continued to accumulate through the early weeks of storage. In samples harvested in the same careful manner, and with precautions taken to assure minimal injury as they were placed into and retrieved from a factory storage pile, raffinose levels were similar to those of controlled storage samples, whereas invert levels were significantly greater in the former (Fig. 1). Greater microbiological action on pile stored samples may be the underlying cause of the greater accumulation of invert sugar.

FUTURE PLANS: This large experiment is related to a previous experiment in which sugarbeets were stored for longer periods. The full data from each experiment have been provided to the cooperating group, but the two sets of data await further analysis, comparison, and publication. The original goals of this project have been met, and no further experimentation of this type is planned.

Fig. 1 Changes in Raffinose and Invert Sugar Levels with Time in Storage

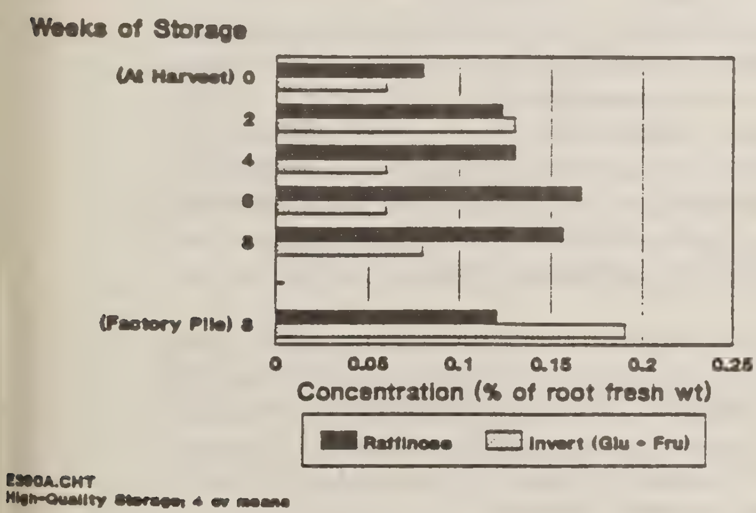
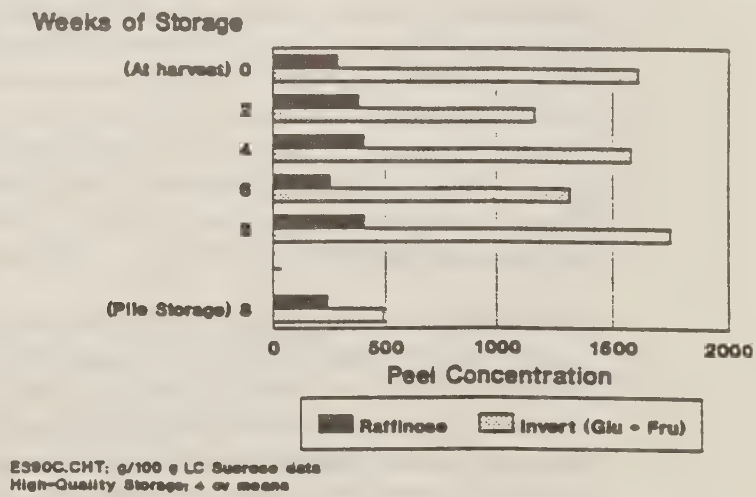


Fig. 2 Raffinose and Invert Sugar in Peel (as % of whole-root concn, g/100 S)



BIOCHEMICAL CHANGES IN SUGARBEETS STORED UNDER THREE CONTROLLED TEMPERATURE REGIMES

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CRIS: 5402-21220-002-00D

PROBLEM: The trisaccharide raffinose [galactosyl sucrose; [α-D-galactopyranosyl-(1→6)-α-D-glucopyranosyl-(1→2)-ß-D-fructofuranoside] is a normal sugarbeet chemical constituent that is especially detrimental to processing quality. Raffinose not only interferes with sucrose crystallization, but because it is almost twice as dextrorotary as sucrose, it can cause serious errors in polarimetric sucrose analysis, the only technique available for rapid analysis of thousands of samples daily in processing plants. There have been suggestions in the literature that raffinose accumulates with prolonged cool storage (near freezing), and that warmer storage temperatures might be desirable. We have developed a high performance liquid chromatographic (HPLC) analysis in which raffinose, sucrose, and the monosaccharides glucose and fructose can be determined accurately, making it possible to determine the effect of storage temperature on raffinose accumulation.

APPROACH: In collaboration with a sugarbeet processing company, sugarbeets of three commercial varieties were harvested by hand from test plots, bagged, and transported carefully to laboratory and storage facilities. Ten replicate samples of each cultivar were analyzed at harvest, and ten reps of each cultivar were stored for 95 days at 35°F, 45°F, or 55°F (1.7°C, 7.2°C, or 12.8°C). Sucrose, raffinose, glucose and fructose were determined by HPLC analysis of deionized extracts prepared by aluminum clarification of sugarbeet brei samples (a standard method for extract preparation for polarimetric sucrose determination).

FINDINGS: [Data are expressed as % based on potassium (K), a component that does not change in sugarbeets during storage, to avoid possible effects due to differential dehydration under the different storage regimes.] Raffinose in extracts of sound beets at harvest ranged from 27 to 35% on K. After 95 days of storage, raffinose content had increased in each variety at each storage temperature (Fig. 1). Contrary to literature reports, low temperature storage did not promote raffinose accumulation to a greater extent than higher temperatures. Raffinose concentrations at each storage temperature essentially mirrored increases in glucose and fructose. In contrast, as is well-known, sucrose losses increased with increasing storage temperature (Fig. 2). Varieties differed in raffinose accumulation and sucrose loss.

INTERPRETATION: Raffinose accumulates during prolonged periods of low temperature storage (constant 35F in these studies), but accumulation is even greater at higher temperatures (45F or 55F). There is no reason to attempt to store sugarbeets at conditions other than freezing or near freezing, as raffinose, glucose, and fructose (all detrimental to processing) accumulate and sucrose declines with increasing storage temperature. Varietal differences in accumulation rates for these sugars indicate that selection for better storage properties may be feasible.

Fig. 1 Raffinose At Harvest and Under Three Controlled Storage Temperatures

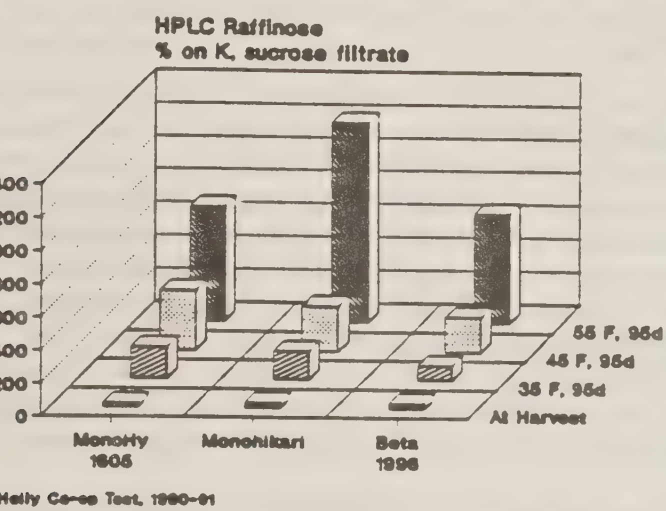
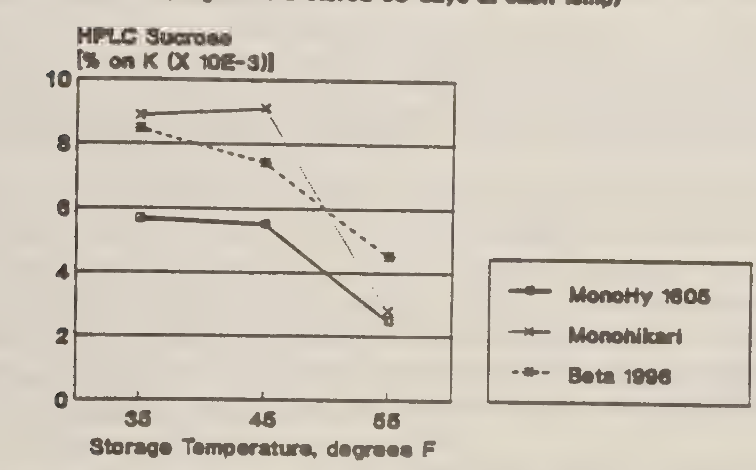


Fig. 2 Effect of Temperature on Sucrose Loss in Storage
(Sugarbeets stored 95 days at each temp)



ORGANIC ACIDS OF THE SUGARBEET ROOT

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CRIS: 5402-21220-002-00D

PROBLEM: Organic acids occur in the mature sugarbeet root at relatively low levels, but they also may be formed as a result of changes in carbohydrate structures during storage. The acids present and their quantities are of importance in sugarbeet processing. In particular, organic acids that form insoluble calcium salts play an important role in the precipitation of calcium in the liming/carbonation steps used to "purify" (remove chemical classes of undesired components) of the sucrose-containing juice. Because of their structural similarities, organic acids are difficult to separate and analyze; little is known about their occurrence in sugarbeets, or about the changes that may occur in their concentrations during storage. As a part of our on-going investigation of the biochemistry of the sugarbeet "peel" and the feasibility of peeling as a means to improve processing quality, we needed to determine the distribution of organic acids within the root, and their quanti-tative changes under various storage conditions. The initial requirement for such a study was the development of a suitable analytical method.

APPROACH: Because organic acids are anions at moderate pH, HPLC with an anion exchange or ion exclusion column seemed the most feasible technique for organic acid analysis in sugarbeet. A search of the literature yielded several HPLC methods for organic acids, but none was entirely suitable for sugarbeet analysis. We chose to develop a new method based on a newly available column type. The method also had to be insensitive to sugars, or had to include steps to remove the large amount of sucrose and other sugars present in sugarbeet aqueous extracts.

FINDINGS:

Numerous trials were made with several columns and two detector types. The BioRad Aminex HPX-87H ion exclusion column, designed specifically for organic acid analysis, and diode array UV detection were selected as most suitable for our needs. Eluants and operating parameters were optimized to separate standards of the major known sugarbeet organic acids. It was necessary to operate the column at elevated temperature to obtain satisfactory separations in a reasonable time and with reasonable solvent flow rates.

Sugars co-elute from the ion exclusion column at approximately the same times as organic acids; thus, it is impossible to detect low levels of organic acids if a detector sensitive to both types of compound is used. Many trials of ion exchangers and other preparative separatory materials were made; the large quantity of sucrose present in sugarbeet extracts is extremely difficult to remove, and we were not able to find an ion exchange material that could remove the sugars, yet allow complete recovery of organic acids. As a result, the final method does not remove sugars from the extract to be analyzed, but instead uses a detector and detector conditions insensitive to sugars, but sensitive to organic acids.

The final method is satisfactory for the separation of sugarbeet organic acids, with excellent component recovery, linearity, and precision. Analytical conditions are:

Column:	BioRad HPX-37H ion exclusion, 4.6 X 300 mm (plus in-line prefilter and H^+ guard column)
Heater:	60°C
Eluant:	0.01 N H_2SO_4, 0.5 ml/min (isocratic)
Injector:	Waters WISP autosampler, 15 μl
Detector:	Photodiode array, monitored at 220 nm; 0.1 AUFS
Electronic integrator/recorder	

Literature reports listed oxalic and citric acids as the major organic acids in sugarbeets at harvest, with much smaller amounts of several other acids. In a small preliminary test, we determined concentration ranges that could be expected in sugarbeets at harvest, and in peel and peeled root ("interior"). In this limited test, succinic acid was the predominant organic acid, followed by oxalic, citric, and malic acids (Table 1).

Table 1. Concentration ranges for organic acids in sugarbeet peel and interior at harvest.[1]

	Ppm in sucrose filtrate	
Acid	Interior	Peel
Oxalic	30-130	330-500
Citric	30-130	400-1000
Malic	20-35	15-115
Succinic	250-370	640-800
Fumaric	2-2.7	4-6
Acetic	trace	trace
PCA[1]	trace	trace

[1]This was a limited, preliminary test (n=6 samples of each tissue type). Ranges may be expected to change as more data are obtained.

[2]Pyrrolidine carboxylic acid

INTERPRETATION: A new procedure for analysis of organic acids in sugarbeets has been developed and optimized. On the basis of preliminary data, it appears that in sugarbeets at harvest, peel levels of the major organic acids are several-fold their concentrations in the remainder of the root. If further research confirms this preliminary evidence, the organic acid data would support the conclusion that peeling sugarbeets could improve processing quality.

FUTURE PLANS: Organic acid HPLC analyses recently have been completed on a large, designed experiment that included 4 cultivars and 4 periods of time in high quality storage (2, 4, 6, and 8 weeks at 4°C and near 100% RH). Data analysis will be completed in the current CY. No further experimentation is planned at this time, but the method will remain available in our laboratory to answer future questions about organic acid accumulation.

WATER MANAGEMENT RESEARCH UNIT

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WATER USE AND LABOR REQUIREMENTS FOR IRRIGATED CROPS

E. Gordon Kruse
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM:

Accurate estimates of crop water use are necessary for irrigation scheduling, which in turn allows good irrigation water management. High water tables often exist under irrigated lands as a result of inefficient irrigation systems and subsurface geological conditions. Such water tables occur under much of the irrigated land in the Upper Colorado River Basin. Irrigation management should take crop water use from shallow water tables into account, and modify irrigations accordingly. Also, more information is needed on the benefits of level basin irrigation, relative to more traditional methods of surface irrigation.

Vegetables and other specialty crops are often grown under plastic mulch, which can affect both water use and the efficiency of application of irrigation water. Little information is available on mulch effects.

APPROACH:

We used hydraulic weighing lysimeters to determine effects of high water tables on corn, alfalfa and wheat in the Grand Valley from 1981 through 1989. The lysimeters contained 60 and 105 cm deep water tables, supplied with 0.7, 3.0 and 6.0 dS/m ground water. Effects on surface irrigation requirement, water use efficiency and leaching requirements were evaluated.

Time and water volumes required for conventional siphon tube and gated pipe irrigation, and automated level-basin irrigation of fields on the CSU Fruita Research Center were monitored in 1989. Analysis was completed in 1991.

A cooperative study with the CSU Dept. of Horticulture continued in 1991, to determine effects of plastic mulch on water use, rooting pattern, and irrigation scheduling of vegetable crops irrigated by trickle or furrow methods. Small plot treatments were evaluated by root sampling, soil water monitoring and statistical analyses of plot yields and water use efficiencies. Results of a second study, which examined soil nitrates under a range of irrigation and fertilizer applications to onions in the Arkansas River Valley, were analyzed.

FINDINGS:

Analysis of shallow, saline ground-water contribution to crop needs was extended to determine leaching requirements under those conditions. Results for winter wheat were published during 1991. A manuscript that includes results for all crops studied and also includes the leaching information is in the ARS peer review process. A CSU graduate student used the same data to verify a simulation of root zone salt and water conditions over shallow water tables.

Detailed records of gross water use and labor required for irrigation of all fields on the main 80 acre portion of the Fruita Res. Ctr. during 1989, were analyzed and a manuscript drafted. Furrow irrigation

of the larger fields at the Fruita Research Center required labor averaging 1.04 hours per hectare per irrigation. For large level benches the average total labor requirement in 1989 was 1.74 hr/H/irr, of which only 0.14 hr/H/I was actually spent in turning on and off the water flow to the basins.

In 1990, root mass of acorn squash was greater on non-mulched, furrow irrigated plots than on similar plots with plastic mulch. Root mass was significantly greater in the top 30 cm of soil than at greater depths, although roots were easily measurable at 45-60 cm depth. Yields were equal for all irrigation treatments under plastic mulch and about 20 percent lower for the non-mulched treatments. Water application efficiencies were highest on mulched plots with lowest water applications. Only mulched, furrow irrigated treatments showed much water extraction by plants from 30-60 cm depth. Two years of irrigation/fertilizer.interactions on onions in the Arkansas Valley showed that initial soil nitrate-N levels of 63 ppm and irrigations equal to 0.75 the scheduled amount were sufficient for maximum yield. Larger applications caused N to leach below the root zone.

INTERPRETATION:

Net water applications to level basins in 1989 exceeded irrigation requirements by 30 to 50 percent. On furrow irrigated fields, requirements were exceeded by 50 to 400 percent and gross applications were even greater. The data indicate greater labor requirements for irrigating comparably sized level basins.

Squash grown under plastic mulch produced higher yields than non-mulched squash under all irrigation treatments. Trickle and furrow irrigation plots supplied at half the scheduled rate yielded as much as a furrow plot irrigated at the scheduled rate, indicating that even lower water applications might be adequate under mulched conditions. More information on root distributions is needed before conclusions can be drawn, but lateral root development seems to be reduced when trickle lines apply water directly over the squash rows. Root depth, and presumably water extraction, extends to at least 60 cm depth for mulched, irrigated furrows.

Pre-season analysis of soil nitrates is important to determine if additional nitrogen should be supplied for onion culture. Irrigation applications should be no greater than those called for by the USDA irr. sched. program, if maximum yields are to be obtained with minimum opportunity for ground-water pollution by nitrates.

FUTURE PLANS:

Publication of papers in 1992 on contribution of high, saline water tables to crop needs and on water and labor requirements for different irrigation methods will complete those studies.

A dissertation project did not result in a complete, usable model of root zone salt and water conditions over shallow water tables. Continuations by other students will be encouraged.

Cooperative studies with CSU Dept. of Horticulture on the effect of plastic mulches on root and water distribution, and on fate of nitrates under irrigation scheduling of onions, may be continued for a third year, if found to be necessary after analysis of 1990/1991 data.

DESIGN CRITERIA & INTEGRATED MANAGEMENT TECHNOLOGY FOR SURFACE & CENTER PIVOT IRRIGATION SYSTEMS

Dale F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-03S
SCA 58-5402-0-003

PROBLEM: The management of irrigation systems to apply water and chemicals is needed to increase water use efficiency and prevent the degradation of ground water. The integration of management is important to provide for improved operation. When managing any resource by itself can lead to mismanagement of another resource. The implementation of integrated systems requires the necessary hardware and software for testing and developing new concepts.

APPROACH: A linear move system for experimental water and chemical application requires a control much more sophisticated than one for normal field operations. The different water treatments required are often applied by changing frequency and/or depth of an irrigation. The system to be installed at the CSU North Ag Campus will require flexibility in both time and space. A possible solution for the problem of varied application needs along the pipeline is to apply the concept of pulse irrigation. Pulse irrigation is based on a series of pulses, where each pulse is composed of the operating (on) and resting (off) phases. Solenoid valves installed upstream of one or more spray heads enable the flow control. Because each electrical pulse causes the valve to perform one complete cycle, the frequency of operation is limited by the valve's response time. When compared to mechanical valves, solenoid valves are usually lighter and more compact. Unlike manual actuators, solenoids allow remote and automated control with greater reliability.

FINDINGS: An indoor lateral pipe with three spray heads was built to simulate a linear system and to allow the study of solenoid valve's operation characteristics. Solenoid valves can be installed at different positions in the system and remotely controlled. Seven different brands of solenoid valves were tested and their performance under different operation frequencies evaluated. One brand was used to determine the influence of pulse irrigation on the water distribution patterns from spray heads. It was found that there is a small decrease in the application radius but not much change in the pattern shape. As a consequence, the uniformity of application will not be affected. The tests also showed that the valve's response time will vary with the different brands and nozzle sizes.

INTERPRETATION: The main conclusion is that pulse irrigation is feasible with the brands of solenoid valves commercially available but the influence of the valve's response time on the depth of water applied must be further investigated and quantified. This will provide an excellent experimental tool for studying the integrated management of water and chemicals. It is possible that the system will have value for commercial application as well as for research studies.

FUTURE PLANS: One or two brands of solenoid valves will be selected for further tests. The selection will be based on tests to evaluate their performance in terms of response time, repeatability, etc. The tests will also allow the selection of the best operation frequencies. Pressure variations in the system caused by pulse operation will be further investigated. The existing mathematical model to calculate the depth of water applied by a linear move system will be modified to incorporate the changes due to pulse irrigation. Field tests will be performed to validate the modified mathematical model.

STUDY THE PHYSICS AND DEVELOP THEORY OF INFILTRATION FOR IMPROVED IRRIGATION

Dale F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-01S
SCA 58-5402-9-106

PROBLEM: Surface irrigation is the method used on about 60% of the total irrigated area. A challenge has been to improve the efficiency of these systems. The infiltration rate of the soil is the controlling factor since it controls the amount of water stored in the root zone. The soil surface is also used as the transmission zone from part of the field to another. The understanding and management of infiltration is important for the design and operation of surface irrigation systems. Surge irrigation is a technique that has been found experimentally to increase the efficiency for surface irrigation. However, the understanding of the physics is not well understood and needs more study.

APPROACH: Field and laboratory studies provided a better understanding of the physics of infiltration. Field studies to measure the compaction from different tillage operations were made. Laboratory studies to run to find the effects of compaction and soil surface sealing. These results will be analyzed with hydraulic models to develop design and operational criteria.

FINDINGS: The mechanisms of consolidation and air entrapment in three intermittently wetted soils were studied in a physical model. Consolidation and consequent reduction in saturated permeability were more pronounced in cohesive than in cohesionless soils. However, persisting cracks provided preferential flow paths and reversed the trend of permeability reduction in the cohesion soils at suctions greater than 20 cm water. Air entrapment was more pronounced in cohesionless sand than in the cohesive soil, and is thus regarded as a potential factor to reduce permeability in surge irrigated sandy soils. While consolidation and surface sealing are mostly surface phenomena, air entrapment is a subsurface phenomenon. More than 90 percent of final consolidation was found to occur during the first 10 minutes into drainage, implying that the extension of off-time in surge flow irrigation beyond such period is not expected to contribute to reduced infiltration from consolidation.

INTERPRETATION: The improved understanding of the effect of consolidation and air entrapment allows a scientific approach to develop the design and operational criteria for surge irrigation systems. Although it has generally been assumed that surface sealing is an important factor in reducing the intake rate and allow for more rapid advance and increase the uniformity of surface irrigation, this did not appear to explain the positive benefit of surge irrigation on sandy soil. The air entrapment gives a reasonable explanation for the improvement observed on sandy soils. The persistent cracks also could explain why we did not see as much benefit for surge irrigation on some of our clay soils.

FUTURE PLANS: The work for the next year will be to focus on developing design and operational criteria by using hydraulic models. The knowledge gained will be used for input to the hydraulic models.

IRRIGATION TECHNOLOGIES FOR SUSTAINABLE FARMING WHICH CONSERVE WATER AND PROTECT WATER QUALITY

Dale F. Heermann
Water Management Research Unit

CRIS: 5402-13000-004-04S
SCA 58-5402-1-129

PROBLEM: The ability to improve the management of our irrigation systems to conserve water and protect our water quality requires new integrated systems to allow the user to meet the national goals and at the same time sustain future food and fiber production. One of the greatest opportunities for more economical systems to provide for sustainable agricultural production is the improvement of management of the total agricultural system. Management of the spatial and temporal variation must be included in future production systems to protect our water quality. The use of Geographical Information Systems (GIS) offer the ability to collect, process, store and interpret large data bases characterizing the variability. The appropriate user friendly systems that can process these data and provide useable management recommendations are needed.

APPROACH:

The CSU Agronomic Research Farm which is currently being constructed will be used for a case study for the development of a GIS model for integrated management. The first step is to define and collect the data bases necessary for model development. Climatic data, Farming land/land use/land cover, soil type, soil fertility as related to nutrient availability, soil productivity, soil moisture availability, crop acreage, crop treatment, planting dates, crop types, fertilizers used, weeds, pesticides used, and water application history will be part of the needed data base. The management algorithms will be developed with the input from the many disciplines that will be cooperating of research projects on the CSU farm.

It will be necessary to study the different GIS packages available and evaluate their capabilities for meeting the objectives of developing the integrated management system.

FINDINGS: Many of the available GIS software packages have been inventoried and their general system characteristics detailed. The programs are capable for operation on both PC and larger UNIX based computers. The PC based programs are much less expensive and appear to have the advantage of being more readily adopted by the farmer. We currently have purchased one PC based program (IDRISI) and have installed a government program (GRASS) on our HP UNIX based machine for further testing.

INTERPRETATION: The main accomplishment is the selection of two GIS packages for use in developing the management model and develop the data bases. The general framework has been investigated with input from a number of disciplines that will be cooperating on the model development. This project is primarily in the planning stages with work just beginning on assembling the data bases.

FUTURE PLANS: The collection of data bases and testing of models for suitability in developing the management models will be conducted in the next year. As the data bases are assembled, the algorithms will be developed for combining the large array of information to provide management useful maps and management recommendations.

SAFETY AND WATER SUPPLY PROTECTION WHEN APPLYING AGRICULTURAL CHEMICALS IN IRRIGATION WATER

E.G. Kruse, H.R. Duke and G.W. Buchleiter
Water Management Research Unit

CRIS: 0500-00032-021-00D

PROBLEM:

Advantages of applying agricultural chemicals in irrigation waters include potential for uniform coverage, low application costs, fewer restrictions on application timing than when mobile, ground based applicators are used, the ability to move the pesticide into interior portions of the plant to reach certain pests, and the possibility of applying materials toxic to humans with minimal human exposure. Among the disadvantages are potential contamination of irrigation water supplies, high levels of dilution of chemicals with irrigation water, and limited ability to pinpoint applications to those portions of the plant or the soil where the pesticide might be most effective.

Several states have researched various elements of "chemigation" and/or have developed laws to regulate the practice. Variations in regulations or in research results suggest that information should be consolidated nationally, and additional research initiated, if indicated. For example, little is known about the functional life of hardware used for chemigation safety, and the interaction of different chemicals and water qualities on the effectiveness of such equipment.

APPROACH: Our initial research interest is with proper design and maintenance of equipment for injecting chemicals into irrigation systems, especially pressurized systems, so that irrigation water supplies are protected from contamination. 1991 was devoted to literature search and contacts with those researchers who have experience in chemigation studies.

FINDINGS:

Dr. Duke visited Tifton, GA for 3 months temporary assignment in late 1991 to collaborate with chemigation scientists and conduct an extensive literature review. He compiled a bibliography of about 700 chemigation related references and collected reprints of some 300 such papers, particularly related to the engineering aspects of chemigation.

A search of literature on chemical injection system hardware revealed some 50 papers and articles. Most of them described the components of the systems and their purposes. Little evidence of research into life expectancy of components was disclosed. The ASAE publishes a Engineering Practice for "Safety Devices for Chemigation". Several states have adopted this Practice, in whole or in part, for their regulatory purposes. Colorado, through the Commissioner of Agriculture, regulates chemigation systems in the state. Systems are inspected every two years to assure their compliance with standards.

INTERPRETATION: Chemigation is an economically viable means of applying agricultural chemicals. Studies in the physiological and engineering areas have demonstrated that with uniform application of the

appropriate chemical at the appropriate time for best efficacy on the target pest, less chemical may be needed than for conventional preventive treatment. If this method is to remain viable, safety equipment must be developed and its reliability proven to the point that there is public confidence in its ability to prevent accidental contamination of water supplies.

FUTURE PLANS: The effectiveness of current mechanical injection equipment to prevent water source contamination depends to a high degree on nature of chemicals injected, ambient operating conditions and the degree of operator care and maintenance. This effectiveness needs to be evaluated from samples of a large number of such systems that have operated for varying lengths of time and under varying conditions. Several state governments have existing inspection programs. They will be approached to see if their data files would be available for ARS analysis. If so, such data will be analyzed and results published. Results may lead to laboratory or other experiments to provide means of accelerated mechanical and chemical testing of components to project their useful life.

UNIFORMITY AND EFFICIENCY OF CHEMICAL APPLICATION THROUGH IRRIGATION SYSTEMS

H.R. Duke, W.C. Bausch, G.W. Buchleiter, D.F. Heermann, R.E. Smith and E.E. Schweizer
Water Management Research Unit

CRIS: 0500-00032-021-00D

PROBLEM:

It is imperative for efficient chemical application that the water be applied uniformly and in depths to control leaching; that the chemical be mixed uniformly with the water; that applications be timed for optimum effectiveness; and that the irrigator have the knowledge of variability in soils, crops, and application and the tools to allow him to manage water and chemical application under variable soil, crop, and application conditions.

Self-propelled irrigation systems can apply water and solutions of agricultural chemicals uniformly to growing crops. Studies indicate that "chemigation" can reduce the amount of chemical necessary for pest control when special equipment capable of spraying the underside of leaves is used. Chemigation holds special promise when used with good irrigation water management for minimizing leaching of agricultural chemicals toward the water table.

APPROACH:

We have assisted the College of Agriculture at CSU in design of the irrigation system for the new North Ag Campus under construction near Anheuser Busch. As a part of that system, a linear-move sprinkler will be installed. We will fit this sprinkler with several sets of irrigation nozzles, as well as equipment necessary for injection of nitrogen fertilizer. We will work cooperatively with CSU and other ARS researchers (Follett, Shaffer, Hinkle) to develop field scale research under this linear system to evaluate coordinated water/nitrogen management practices. We will also develop systems appropriate for applying nitrogen and water as needed for crop uptake, so as to maintain low levels of water and nitrogen in the soil over the winter period when they are subject to leaching by offseason precipitation.

Geographic Information Systems will be applied to field scale problems to develop methods of providing information to the grower which will allow him to best manage his water and ag chemical applications. Combining topographic information, soil data, irrigation system uniformity and water and chemical transport models will allow evaluation of the effects of management decisions, including economic aspects, when applied to situations where variability of several parameters exists.

Efficiency and uniformity of sprinkler irrigation are effected by climatic influences, including evaporation while water is airborne, evaporation from wet surfaces, and reduced transpiration caused by a humid microenvironment in the vicinity of irrigation. Scientists disagree on the extent of these effects. Both plant based and meteorological methods of direct measurement of transpiration and ET will be used to attempt to determine the effects of these microclimate changes.

FINDINGS:

Water distribution data from 60 SCS center pivot tests were analyzed to determine the most appropriate statistical distribution function (normal) to describe these data. This function was then used with linear functions describing water/yield, water/leaching, and nitrogen/yield relations to develop an analysis of the most appropriate irrigation scheduling depth to maximize net return for a given economic scenario. It was shown that the conventional recommendation to irrigate for maximum yield results in an economic loss under most any economic scenario, and that this loss is accentuated by a system delivering poor uniformity of water application.

Stem flow sensors measured water flux rates in corn plants during several periods in 1991, both during irrigation and in plots when irrigation was not occurring. Preliminary analysis of the data show that detectable differences in transpiration were measured between plants subject to wetting and those not wetted. Data from Bowen ratio apparatus were also taken in corresponding plots during irrigation and non-irrigation periods, but these data have yet to be analyzed.

INTERPRETATION:

The need to evaluate the performance of sprinkler irrigation systems is of particular importance when the systems are used for application of chemicals. Methods which include economics into the management's selection of application depth can give the grower an idea of the return he can expect from investing in irrigation system improvement. This method shows the costs, based on the irrigator's own economic scenario, associated with improperly selected management scenarios in terms of water wasted, environmental consequences, and loss of yield.

Determination of impact of drift and evaporation on ET is necessary to apply the most appropriate amount of water for control of chemical transport in the soil while maintaining optimum crop yields.

GIS will provide a convenient means of integrating a huge volume of data into a form that can be used for real-time management decisions for responsible management of water and chemicals.

FUTURE PLANS:

Field plots at AERC will be planted to corn in 1992, with nitrogen treatments superimposed on two water treatments. A chlorophyll meter will be used to schedule prescription applications of N to part of the plots. Simultaneously, measurements will be made of canopy reflectance, soil water and N concentration, tissue N concentration, canopy temperature, leaf area index, and light penetration through the canopy. If remote methods of measurement can be correlated with more direct measurements, then rapid assessment methods for large areas may be developed to allow application of nutrients in the most prudent manner.

Exploratory data obtained with stationary Bowen ratio systems located upwind and downwind of a center pivot lateral will be analyzed to determine ET differences created by the irrigation system that can be related to spray drift.

The location of instrumentation for Bowen ratio systems above the surface of interest is not agreed upon by scientists and, therefore, very confusing in implementation of the technique to obtain usable data. Consequently, a field study to investigate positioning effects on stationary Bowen ratio system data will be conducted provided a suitable site is located. These stationary systems will be compared to a spatial averaging system that compared very well to a precision weighing lysimeter.

INTEGRATED MANAGEMENT SYSTEMS FOR SELF PROPELLED SPRINKLER IRRIGATION SYSTEMS

G. W. Buchleiter, D. F. Heermann, H. R. Duke, R. E. Smith and E. E. Schweizer
Water Management Research Unit

CRIS: 5402-13000-004-02T

PROBLEM: Center pivot irrigation systems are used extensively in the central Great Plains and in the Pacific Northwest. There is a continuing need to improve water management, to minimize environmental damage from overirrigation and to minimize energy costs. The interactions of the various aspects of crop production (e.g. water and nutrient use, pest control) as well as the size and complexity of irrigation systems make it difficult to manage effectively without assistance from a computer. The ability to resolve potentially conflicting crop production practices and to respond quickly to changing operating conditions can enable the farmer to improve irrigation practices and reduce production costs.

APPROACH:

Our approach is to develop microcomputer software that provides recommendations the farmer can use to improve his management. For successful adoption, the programs must be easy to use by people with limited computer background. The models used in these programs must be properly calibrated and resolve potentially conflicting crop production practices so farmers are confident of the results and recommendations. We feel the farmer must be knowledgeable and actively involved with these programs, in order to remain committed to using them in the long term.

An irrigation scheduling program, load control program and a pump selection program have been developed and tested. These programs can be interfaced with radio telemetry monitor and control systems to reduce manual data entry and to make it easier to implement the recommendations. Limited technical support is provided to our cooperators to insure successful technology transfer.

FINDINGS:

As part of our technology transfer agreement with Valmont, the prototype software for monitoring and controlling multiple center pivots was completed and field tested. A program for analyzing operational data to determine irrigations for use in the irrigation scheduling program was developed. Operational data collected by the monitor and control system were used to test and debug this program. Some additional logic was required to reduce the number of errors in determining irrigations.

Although the monitor and control program was well received, Valmont has subsequently redesigned the pivot panel and included some additional capabilities. They also intend to market a weather station which will greatly enhance the capability for irrigation scheduling.

After analyzing the difficulties we were likely to experience in integrating multiple programs in real-time mode, we concluded a multi-tasking environment such as WINDOWS would be advantageous. Consequently we have begun development of a newer version under the WINDOWS environment.

The cooperator (EOFC) in Oregon has made significant progress in implementing irrigation scheduling and the pump optimization program as part of their real time operation. Our role has been mainly

advisory working with their irrigation manager and their engineering consultants. The irrigation manager is pleased with the results of the irrigation scheduling program that was modified last year.

We reviewed the available 1990 load control information for a potential cooperator in central Wisconsin and found it inadequate to make an analysis.

INTERPRETATION:

Several new products offering remote monitoring and control have been introduced by several companies indicating greater interest in this management approach. Valmont and our cooperators are still very interested in and enthusiastic about making the computerized monitor and control systems work properly. They are marketing these systems more aggressively in production agriculture and municipal land application waste disposal systems.

The level of acceptance of these programs depends on the direct cost savings attributed to the system, their ability to incorporate the recommendations into their management style, and their ease of use.

FUTURE PLANS:

We have continued the technology transfer agreement with Valmont to jointly develop second generation monitor and control software. We intend to expand this software for linear move systems and will do field testing on the linear move system at the CSU Stroh Farm. This system will be used for irrigating research plots and will be capable of applying fertilizers. We will continue to work with several cooperators in eastern Colorado to troubleshoot system problems for the 1992 growing season and to implement scheduling. We will continue to provide limited technical support for the pump selection program in eastern Oregon and Washington.

We plan to use system engineering concepts to plan and integrate the various management models so they can be maintained and upgraded easily. We are planning an interdisciplinary project with R. Follet and M. Shaffer to develop a nutrient scheduling model that recommends timing and amounts of fertilizer. Use of this model will not be limited to self-propelled irrigation systems but will provide recommendations for other irrigation systems as well.

A potential cooperator in central Wisconsin has contacted us for assistance in implementing a load control program for decreasing peak electrical demands. We intend to analyze their 1991 operational data before implementing a program which appears to be very similar to the program that we field tested in Colorado in 1982-1984.

As part of the irrigation system to be installed at CSU's North Ag Campus, we have helped arrange for procurement of a linear move sprinkler system to irrigate about 25 acres. This system will be equipped with Valmont's computerized control panel and a radio telemetry system. Monitor and control software developed for the center pivot will be modified as necessary to work for linear systems. Interfaces will be developed to allow application of nitrogen fertilizer according to a predetermined pattern to plots under the sprinkler.

IRRIGATION SCHEDULING FOR WATER AND CHEMICAL MANAGEMENT

D.F. Heermann, H.R. Duke, W.C. Bausch, and G.W. Buchleiter
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Concepts of irrigation scheduling by soil water balance from meteorological data have been available for more than two decades. Farmers are realizing that management of water is a key to control of fertilizer and pesticide leaching, and are anxious to improve their operations. Researchers have developed numerous models for management of irrigation water and nitrogen under irrigated lands. There is a need for consensus on the most appropriate algorithms for inclusion in user-oriented models and for assembling such models, distributing to potential users, and supporting the models once distributed.

APPROACH:

Work continues to support the ARS irrigation scheduling program developed by this group. A Colorado weather data base is being developed to make necessary data available to those who wish to use the program.

Potential users and their various needs will be identified by a ARS scientists from Ft Collins and Pullman, university scientists from Texas A&M, Nebraska, Oklahoma State, Univ Florida, and Michigan State, and by SCS personnel. Existing models will be studied to determine the most appropriate algorithms from each to meet these needs. Technical aspects of model formulation will be conducted by the ARS and university scientists. SCS Technical Information Services Division in Fort Collins will develop input/output formats and will be responsible for distribution and user support for the models.

FINDINGS:

Meetings have been held with the scientists and SCS advisors described above to identify potential users and to determine the necessary functional requirements for two classes of water/nitrogen management models. It has been decided to develop models for both planning and operational purposes to meet the needs of SCS and other local end user groups.

Requests from growers for the scheduling program continue to be strong. We have distributed more than 90 copies of the program throughout the world during the past 3 years. We continue to aid technology transfer, assisting SCS and Extension personnel by checking instrument calibration, trouble shooting instruments, and answering questions about operating the program. Duke is coordinating efforts of Extension and SCS personnel with those of CSU's Plant Pathology Dept to install multiple use weather stations with the sensors necessary for both irrigation scheduling and plant disease forecasting, and the group has installed nine weather stations as part of a statewide network. Our research group has acquired a minicomputer, on which we are logging the data from the weather stations. We also provide direct support to several technically oriented farmers throughout the U.S. who are using the programs. Particularly Buchleiter and Duke have responded to numerous requests from Extension, SCS and consultant groups to participate in farmer-oriented water management workshops throughout the Plains.

INTERPRETATION: Growers are increasingly concerned about the potential for leaching of

agricultural chemicals from improper irrigation management. As water quality concerns grow, irrigators will be required to control the movement of agricultural chemicals into the nation's water supply. One of the primary means of implementing such control is by control of the water, which is the principal means of chemical transport. The availability of programs useable by the irrigator himself will allow more informed day-to-day decisions regarding management of water, and the cooperative program development represents a major commitment by ARS to support other action agencies within the Department. Incorporation of crop growth models and chemical transport models will further enhance the grower's ability to control chemical transport.

FUTURE PLANS:

The group identified will continue to develop functional requirements of water/nitrogen management models. Numerous existing models will be studied to determine which contain algorithms that may be used to meet the requirements defined, and these algorithms will be assembled into technically appropriate models. These models will be turned over to SCS programmers who will be responsible for developing input routines and both graphical and tabular output format. We will continue to provide guidance to these programmers and assist with validation of the models developed.

We will continue to provide limited technical support to SCS and Extension personnel and to growers implementing the current scheduling program. We will collect and process weather data from the developing Statewide network for the short term. If plans in progress result in CSU providing assistance to connect AERC facilities with the main campus computer network, then these data will be universally available to local end users for irrigation scheduling and pest forecasting purposes.

APPLICATION RATES, INFILTRATION AND RUNOFF IN IRRIGATION

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Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM:

Conventional design methods regarding the relationship between application rate and potential runoff under sprinklers are still based on infiltration relations implicitly assuming instantaneously ponded surface conditions or a single rate-independent intake curve. As a result, there is often conflicting evidence given as to appropriate action to reduce runoff: that is, should the irrigator apply smaller amounts more frequently (which will result in a wetter soil surface) or apply large amounts less frequently to allow the surface to dry between irrigations? Design methods are also to properly account for the effects spatially varying soil properties, the effect of redistribution between wetting events, and the effect of the occurrence of runoff on total distributional efficiency for a given topography.

Rising energy prices and limited water supplies in some areas are encouraging the use of low pressure nozzles and LEPA systems to reduce energy costs. Reduced application pressures generally means a smaller application pattern and a higher application rate. Usually this high application rate exceeds the local soil intake capacity causing the potential for runoff, especially on significant slopes. Even under more conventional types of sprinklers, runoff can be a problem, particularly in areas of large slope and heavier soils. Irrigators are expressing an interest in independent control of small sections of the sprinkler as a means of minimizing the effects of soil and topographic variability on runoff or excess leaching.

APPROACH:

Research this CY has focused on two theoretical problems concerning infiltration estimation. The first is how to treat a field with spatially varying soil properties. Experimental data from a field sampling experiment in Germany were used to characterize the random spatial variations in soil hydraulic characteristics. Then these variations were included in a simulation experiment based on the solution of Richards' equation, to see what characteristics the field as a whole would exhibit in relation to the statistics of the hydraulic characteristics. In effect, the study asks the question, Are there effective mean soil characteristics that can be deduced from soil samples, and if so how can these be found.

A second study has focused on the development of an analytic model to estimate redistribution of soil water between wetting events, for almost any soil type. Current analytic infiltration theory does not cover the elongation of the wetting profile between wetting events. An analytic model for description of the redistribution of water, as well as the infiltration function for re-application on a wet profile should compare with the solution of Richards' equation. A model is also required for the effect of initial wetting profile development at rates less than those which can cause runoff, on the infiltration function for a subsequent increased rate. This is a case commonly encountered in rainfall hydrology and under center pivot systems with significant overspray in advance of the arrival of the major sprinkling area.

When these complications have been incorporated into an analytic model, it will be possible to form a robust infiltration model that will have the capability to simulate most any scenario under the area of irrigation, at any point on a field which will have any variety of wetting pattern, and to simulate the resulting location and extent of runoff, if any.

FINDINGS:

Studies which simulated field-scale water movement where soil variations exist as described by the German field data show a marked difference between the static mean effective soil hydraulic parameters and those exhibited by soil where a wetting front is advancing from the surface. It was observed that the results were not significantly different between an assumption of variable saturated water contents and an average saturated water content. This is no doubt due to the symmetrical (normal) distribution for this parameter.

This type of result is not surprising given the highly non-linear nature of the flow equations. An additional result was the derivation of semi-analytic results for variations in saturated conductivity alone, when ponded infiltration boundary conditions were used, or when kinematic downward flow of water is assumed. But of greater and more practical interest is the action of the field as a whole considering the interactions of soil water hydraulic parameters. Another extensive data set has been obtained for study of this important part of the problem.

A relatively simple model for redistribution of water between rain pulses or irrigation pulses has been developed. It allows for surface evaporation during the hiatus, and simulates relatively accurately the infiltration capacity at the end of the interval. It is applicable to a rather wide variety of soil types.

INTERPRETATION:

As the trend to use low pressure sprinkler systems continues, irrigators must be made aware of the tradeoffs involved. Controlling potential runoff is essential not only for reducing energy usage but also for minimizing water quality degradation from erosion and leaching of chemicals.

The ability to simulate realistically how the soil responds to various input patterns and spatial variations is crucial to studying the potential for improved irrigation efficiency and management of chemicals which are applied either with or separately from irrigation. Scientists must be able to account for both spatial variation of soil properties, and the complexities of the interaction between input rates and infiltration rates.

FUTURE PLANS:

As the theory of infiltration is improved and refined, field studies are in order to evaluate the applicability of the theory. Knowledge of soil spatial variability important in itself, but also is important in relation to its masking effect when soil infiltration theory is being evaluated. Field experiments at the new CSU experimental farm will be designed to test several aspects of the theory and methods indicated in this research.

Field experiments and mathematical models will be used to evaluate appropriate management schemes for different soils to ameliorate problems of runoff and translocation under sprinkler systems. Initial field studies will focus on characterizing the uniformity or variability of the soil's hydraulic characteristics.

IRRIGATION WATER MANAGEMENT USING REMOTELY SENSED INPUTS

W. C. Bausch and H. R. Duke
Water Management Research Unit

CRIS: 5402-13000-004-00D

PROBLEM: Irrigation scheduling models utilize reference ET and time dependent crop coefficients to estimate actual crop ET. That is, the planting date and the occurrence of effective cover (some future date) are required as independent variables to calculate drivers which are percent of time from planting to effective cover and elapsed days after effective cover. Thus, planting date marks the beginning of the time line. Henceforth, a crop coefficient can be calculated for each calendar day. The 'crop coefficients' used to adjust computed reference evapotranspiration for a specific crop in a specific field are based on averages of several years data, and reflect an 'average' crop development. Whenever crop growth rates depart from this average rate, the time-driven crop coefficients may depart significantly from those published. Consequently, crop ET may be different than estimated. Under such conditions, it is necessary to make adjustments to these crop coefficients as the crop phenology changes in the field. Techniques are needed whereby an individual grower can adjust the crop coefficient to a value appropriate for the stage of development of his specific crops.

APPROACH:

Field corn, *Zea mays* L., cultivar Pioneer 3732, was planted under the two-tower center pivot sprinkler at AERC. Reflectance of the crop/soil scene in four specific wavebands (0.45-0.52, 0.52-0.60, 0.63-0.69 and 0.76-0.90 μm) was computed from measurements of reflected and incoming light using intercalibrated radiometers. Two different soils maintained in a dry and wet state were alternately inserted under the canopy in a common target area to determine background color effects on the composite crop/soil scene. Leaf area data were taken to compute leaf area index.

Photographs were taken of several crops at frequent intervals during 1989 thru 1991. Simultaneously, measurements were made of climatic data, light penetration of the canopy, and leaf area index.

FINDINGS:

Our past research has shown that the normalized difference (ND) vegetation index could be transformed into a reflectance-based crop coefficient (K_{cr}) for corn for the lighter-colored soils over which we had collected data. This is a commonly used index for vegetation assessment because it enhances the contrast between the soil and the vegetation and minimizes the effects of illumination conditions. However, it is very sensitive to the optical properties of the soil such that for a given amount of vegetation the ND results in a larger vegetation index over darker soil substrates. Differences in the K_{cr} based on the ND between the light-colored and the dark-colored soil backgrounds during vegetative growth were as great as 40%. Thus, three recently developed indices that are less influenced by soil brightness were evaluated for potentially representing an all inclusive K_{cr} for corn. These were the soil adjusted vegetation index (SAVI), the transformed soil adjusted vegetation index (TSAVI) and a simple reflectance model that corrects the near-infrared reflectance for soil background. Of these indices, the SAVI was superior throughout the vegetative growth stage in minimizing soil background effects. The procedure for transforming the ND into the K_{cr} was used in the transformation of the SAVI into the K_{cr}. The maximum difference in K_{cr} values based on the SAVI between the light-colored and the dark-colored soil backgrounds was less than 6%.

Leaf area index and growing degree day information were calculated for each crop for each photograph taken as the first step in estimating the crop coefficient corresponding to the stage of growth represented by each photograph.

INTERPRETATION:

The K_{cr} based on the SAVI mimics the basal crop coefficient for corn during normal crop development periods with small deviations caused by the soil substrate. Its main advantage is that it can account for variable crop growth rates; the traditional crop coefficient goes astray during these times. Consequently, the K_{cr} is a true representation of the actual crop condition. An occasional update with real-time data or continuous monitoring with on-board, dedicated sensors will keep the basal crop coefficient curve tracking actual field conditions. As such, assuming reference ET is adequately calculated from measured climatic data and the soil input data is reasonable, estimated crop ET is improved. This means that calculated irrigation depths should be similar to the amount of water removed by the crop from its active root zone.

Photographic indices of crop coefficients will provide a means for the grower without access to more sophisticated techniques to update crop coefficients to account for abnormal crop development.

FUTURE PLANS:

During the 1992 growing season, we plan to grow corn under the center pivot at AERC. Each large plot area will be subdivided into different nitrogen application treatments. One large block will be irrigated based on full crop ET; the other one will receive a fraction of that amount. Both blocks will be irrigated on the same day. Canopy temperature and leaf water potential data will be collected to evaluate the water stress imposed on the crop receiving limited water applications. Leaf area and photosynthetic active radiation (PAR) absorbed by the canopy will be collected also. Exploratory data will be gathered using canopy reflectance in wavebands responsive to chlorophyll in the plant leaves for monitoring plant nitrogen content instead of leaf nitrogen content.

Further analysis of the SAVI based K_{cr} will be performed to determine possible limitations to this reflectance-based crop coefficient for corn. The SAVI will be calculated using several corn canopy reflectance data sets representing different years, crop conditions and soils. The soil background reflectance data will be further analyzed with respect to estimating leaf area index; data sets from other experiments will also be utilized.

Work will continue on developing drivers for the reflectance-based crop coefficient. Growing degree days have been tried; this driver tends to minimize differences in individual curves related to different planting dates within the same year but not due to different planting dates for different years.

Data acquired with 4-degree field of view infrared thermometers will be analyzed to determine if there is an optimum view angle to minimize soil temperature effects on canopy temperature during early vegetative growth.

A growing degree method will be used to estimate crop coefficients between emergence and full canopy development as a means of assigning the crop coefficient to each photograph taken during the past three years.

FIELD TESTING THE BIOECONOMIC WEED/CORN MANAGEMENT MODEL

Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00002-006-00D

PROBLEM: Weed control strategies developed since World War II for corn production have encouraged farmers to apply high rates of prophylactic soil-applied herbicides in anticipation of weed problems. The use of herbicides in corn accounts for roughly 40% of all agricultural herbicide use and 25% of all agricultural pesticide use, for a total of 200 million pounds over the nation's 70 million acres of field corn. EPA recently cited all eight major corn herbicides as having been detected in groundwater. Can weeds be managed in corn, gross margins increased, and herbicide surface loading decreased by employing a bioeconomic weed/corn model to make weed management decisions?

APPROACH: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments were tested on 15 farms in four Colorado counties in 1991. Model decisions were based on weed seed in soil before planting, weed densities after corn emergence, herbicide costs, expected corn grain yield and selling price, and other parameters. CSU personnel took high video footage on cooperator farms from the beginning of soil preparation in the spring through corn harvest.

FINDINGS: Enhanced bioeconomic weed management computer models for soil-applied and postemergence herbicide treatments were tested on 15 farms in four Colorado counties in 1991. Weed management strategies employed by the model vs the farmers revealed that the model plots had: (1) twice as many annual weeds, (2) yielded 1.1 bu/A more grain, (3) returned $10.60/A more gross margin, (4) cost $7.65 less for herbicides, including application, (5) used 7% less soil-applied herbicide/A, (6) used 12% less postemergence herbicide/A, and (7) used 9% less total herbicide/A. Gross margin advantage/farm favored the model in 11 out of the 15 farms. The gross margin advantage for the model averaged $18.65/farm vs $11.70/farm for the farmer. The model was demonstrated to scientists at two workshops and to 150 scientists from the American Society of Agronomy.

INTERPRETATION: Weeds can be managed in corn, gross margins increased, and herbicide surface loading decreased by employing bioeconomic weed/corn models to make weed management decisions.

FUTURE PLANS: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments will be tested on 15 farms in four Colorado counties in 1992. The testing and validation planned for 1992 will complete the 4-year pilot test project that was begun in 1988.

OVERALL SUMMARY OF SEVERAL PARAMETERS
COMPARED RESULTS BETWEEN FARMERS AND MODEL FOR 1989,1990,1991

30-Jan-92 P191\P189-1AV.WK3

DESCRIPTION	1989 FARMER PLOTS	1989 MODEL PLOTS	1990 FARMER PLOTS	1990 MODEL PLOTS	1991 FARMER PLOTS	1991 MODEL PLOTS	AVERAGE FARMER PLOTS	AVERAGE MODEL PLOTS
WEEDS AT HARVEST (NO\30 M OF ROW)								
GRASS	10	8	17	19	31.07	12.80	19.36	13.27
BROADLEAVES	4	3	5	9	1.93	7.40	3.64	6.47
TOTAL WEEDS	14	11	22	28	33.00	20.20	23.00	19.73
GRAIN YIELD (BU\A)	135.09	137.33	162.6	163.2	164.14	165.29	153.94	155.27
GROSS MARGIN ($\A)	315.34	327.59	380.45	386.37	371.33	381.89	355.71	365.28
GROSS MARGIN ADVANTAGE TO								
($\A)	17.26	25.36	13.01	16.74	11.68	18.66	13.98	20.25
(# OF FARMS)	4	9	4	7	4	11	12	27
HERBICIDE COSTS								
PPI ($\A)	7.60	0.00	5.88	0.00	6.04	4.93	6.51	1.64
PREEMERGENCE ($\A)	2.16	3.47	2.94	6.04	4.27	3.36	3.12	4.29
POST ($\A)	6.17	6.60	7.58	6.14	12.50	6.85	8.75	6.53
TOTAL ($\A)	15.93	10.07	16.40	12.18	22.81	15.14	18.38	12.46
HERBICIDE/SOIL LOADING SOIL APPLIED								
PPI (Lb\A)	0.88	0.00	0.66	0.00	0.87	0.91	0.80	0.30
PREEMERGENCE (Lb\A)	0.43	0.65	0.48	0.79	0.47	0.33	0.46	0.59
TOTAL (Lb\A)	1.31	0.65	1.14	0.79	1.34	1.24	1.26	0.89
POSTEMERGENCE (Lb\A)	0.64	1.10	0.79	0.75	0.77	0.68	0.73	0.84
TOTAL HERBICIDE (LB\A)	1.94	1.76	1.93	1.54	2.11	1.92	1.99	1.74

WEED MANAGEMENT IN CORN BASED ON TILLAGE ALONE VS COMPUTER DECISIONS

Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00032-021-01S

PROBLEM: New emphasis on alternative agriculture methods that eliminate or replace part of a herbicide program with mechanical tillage necessitates precision research to determine whether computer-based weed management models can be adapted to provide weed management decisions for alternative farming systems. Additionally, few reports have been published on the effectiveness of mechanical tillage to control weeds in row crops over the last 40 years because weed control strategies developed since World War II for crop production have encouraged farmers to apply high rates of prophylactic soil applied herbicides in anticipation of weed problems. Weeds that emerge within the crop row were difficult to control when they emerge simultaneously with the crop. Thus, if weeds are to be controlled within the crop row with mechanical tillage, better methods must be sought.

APPROACH: The efficacy of non-herbicide mechanical methods versus computer decisions for control of annual weeds under different weed pressures was assessed in corn. Variables were: weed seed banks, pre-cultivation tillage at crop emergence, and cultivation after corn establishment. Experimental design was a split-plot. Weed management strategies (treatments) were randomized within each block in 1990, but not re-randomized in 1991. Thus, each strategy's location in 1991 was fixed. This design allows the tracking of each strategy on a given plot over the 3-year study. This study allows for the assessment of the effectiveness of a rotary hoe vs a flex harrow and a standard cultivator versus an in-row cultivator to control weeds within the row when corn is grown under different weed pressures. Weed control was assessed following each tillage practice. Weed management strategies were compared in terms of weed control, crop grain yield, and gross margin (gross income minus weed control costs).

FINDINGS: In the absence of herbicides, weed populations in corn were reduced significantly with an in-row cultivator as compared to a standard cultivator (see table). As expected, where herbicides were not used, weed populations were considerably higher than where weed management decisions were based on the computer model. Grain yield and gross margin were highest where the weed seed bank was low, the in-row cultivator was used, and the computer model was used.

INTERPRETATION: Weeds are controlled better with the in-row cultivator than with the standard cultivator. Although the in-row cultivator can be used effectively to control weeds within the corn row, weed control, grain yield, and gross margin are higher when the bioeconomic weed/corn model is employed. Corn can be produced without herbicides but fields will be weedier at harvest and gross margins less than where weed decisions are based on the computer model.

Parameter	Total weeds[a] at harvest (#/100 row ft)	Corn stand (#/100 row ft)	Grain yield (Bu/A)	Gross margin ($/A)
Weed seed level				
Low	131a	176a	111.6a	271.20a
High	174a	174a	96.7b	233.50b
Cultivator				
Standard	186a	177a	98.3b	239.00b
In-row	119b	172a	110.0a	265.70a
Weed management strategy				
Tillage only	277a	179a	83.7b	204.10b
Computer model	28b	171b	124.6a	300.60a

[a]Means followed by the same letter for each parameter and within each column are not different.

FUTURE PLANS: This research will be completed in 1992 at the Windsor research farm.

INFLUENCE OF TILLAGE PRACTICES ON WEED MANAGEMENT IN CORN

Phillip Westra and Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00002-006-01S
SCA 58-5402-9-010

PROBLEM: Little recent research has been directed toward many on-farm interactions integral to alternative agriculture, such as the relationship among crop rotations, tillage methods, and pest control. Most of the recent information on weed control with tillage appears in popular farming magazines or in eleven case studies commissioned by the National Research Council (NRC). Five of the eleven NRC case studies dealt with crop and livestock farms, with corn and soybeans being the principal row crops. Weed control practices included rotating crops, tilling just before planting, delayed planting, rotary hoeing (before and/or at emergence), frequent cultivations (2-4 per season), and sometimes handweeding and/or postemergence herbicides. Weeds that emerge within the crop row are difficult to control when the weeds emerge simultaneously with the crop. Thus, if weeds are to be controlled within the crop row with mechanical tillage, better methods must be sought.

APPROACH: The efficacy of non-herbicide mechanical methods to control annual weeds under different weed pressures was assessed in corn. Variables were: weed seed banks (high vs low), surface tillage at crop emergence (none vs rotary hoe vs flex harrow), and directional post-plant tillage (standard row cultivator vs an in-row cultivator). Experimental design was a split block. Weed management strategies (treatments) were randomized within each block in 1990, but not re-randomized in 1991. Thus, each strategy's location will be fixed during the study. This design allows the tracking of each strategy on a given plot over the study. This study allows for the assessment of the effectiveness of a rotary hoe vs a flex harrow and a standard cultivator versus an in-row cultivator to control weeds within the row when corn is grown under two weed seed banks. Weed control was assessed following each tillage practice. Weed management strategies were compared in terms of weed control, crop grain yield, and gross margin (gross income minus weed control costs).

FINDINGS: The rotary hoe was more effective in controlling weeds than the flex harrow (see table). Weeds were controlled again in 1991 within the corn row better with the in-row cultivator than with the standard cultivator. The corn population was reduced by 11% with the in-row cultivator. However, because weeds were controlled better with the in-row cultivator, grain yield and gross margin were highest with the in-row cultivator. Although the in-row cultivator can be used effectively to control weeds within the corn row, weed control, grain yield, and gross margin are usually higher when the bioeconomic weed/corn model is employed. This situation is particularly true when the weed seedbank level is high.

Gross margin Parameter	Total weeds[a] at harvest (#/100 row ft)	Corn stand (#/100 row ft)	Grain yield (Bu/A) ($/A)
Weed seed level			
Low	113b	168a	128.5a320.60a
High	178a	168a	119.1a296.10a
Pre-cultivation			
None	161a	166b	116.2b290.20b
Rotary hoe	124b	165b	133.3a331.80a
Flex harrow	153a	174a	122.0b303.00b
Cultivator			
Standard	212a	178a	109.6b273.20b
In-row	80b	159b	138.1a343.40a

[a]Means followed by the same letter for each parameter and within each column are not different.

INTERPRETATION: Corn can be grown without herbicides but gross margin will usually be less than where weed management decisions are based on the computer model. A non-herbicide approach will necessitate two or more passes with a rotary hoe, followed by two or three cultivations. The use of the in-row cultivator in conjunction with rotary hoeing will control the most weeds and return the highest gross margin.

FUTURE PLANS: The two years of data will be analyzed, summarized and incorporated in appropriate manuscripts for publication. This CRIS will be terminated by September 30, 1992.

ECONOMIC FEASIBILITY OF COMPUTER BIOECONOMIC MODEL FOR WEED MANAGEMENT

Donald Lybecker and Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00002-006-02S
SCA 58-5402-9-011

PROBLEM: Relatively little research has been directed toward the economics of weed management. Few bioeconomic weed-crop models have been developed or field tested. Weed-crop models could aid growers and crop consultants to compare the biological and economic efficiency of many alternatives and present easily interpreted recommendations.

APPROACH: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments were tested on 15 farms in four Colorado counties in 1991. Model decisions were based on weed seed in soil before planting, weed densities after corn emergence, herbicide costs, expected corn grain yield and selling price, and other parameters. ARS and CSU personnel collected and analyzed soil samples from each farm for weed seed, made all plant assessments, and applied all herbicides to model plots. Farmers performed all cultural practices and harvested corn in their strips and in the model plots.

FINDINGS: A survey of Farm Supply dealers was conducted in March to secure current herbicide prices for eastern Colorado. The soil-applied and postemergence weed-corn models were updated to reflect label changes. The model was evaluated at 16 pilot sites, 15 of which provided usable data. Gross income of the model plots averaged $2.90/A more than the farmer plots as a result of slightly higher grain yields. At 11 of the 15 sites the model out performed the farmer plots by an average of $19.00/A. At the other four sites the farmer plots had a higher gross margin of $11.70/A. Over all sites, the model plots outperformed the farmer plots by more than $10.50/A. Over all sites, farmers spent an average of $7.65/A more for herbicides. The farmer herbicide expenditures were more for both soil-applied and postemergence herbicides compared to the model plots. A new computer and printer were purchased in the fall. Work has started on the development of a template to determine the herbicide rates for the weed/corn model based on field soil structure and organic matter. Research has been initiated to develop an environmental herbicide index.

INTERPRETATION: Based on three years of data from 39 farm sites, the model suggests that increased gross margins and reduced herbicide loading can be achieved with the weed management model compared to farmer weed management decisions.

FUTURE PLANS: The two years of data will be analyzed, summarized and incorporated in appropriate manuscripts for publication. This CRIS will be terminated by September 30, 1992.

REFINEMENT OF THE COLORADO WEED/CORN MODEL AND DEVELOPMENT OF EDUCATIONAL MATERIALS FOR END USERS

Donald Lybecker, Phillip Westra and Edward E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-02S
SCA 58-5402-1-115

PROBLEM: Relatively little research has been directed toward the economics of weed management. Few bioeconomic weed-crop models have been developed or field tested. Weed-crop models could aid growers and crop consultants to compare the biological and economic efficiency of many alternatives and present easily interpreted recommendations.

APPROACH: Enhanced bioeconomic weed management models for soil-applied and postemergence herbicide treatments were tested on 15 farms in four Colorado counties in 1991. Model decisions were based on weed seed in soil before planting, weed densities after corn emergence, herbicide costs, expected corn grain yield and selling price, and other parameters. ARS and CSU personnel collected and analyzed soil samples from each farm for weed seed, made all plant assessments, and applied all herbicides to model plots. Farmers performed all cultural practices and harvested corn in their strips and in the model plots.

FINDINGS: The weed/corn bioeconomic computer model proscribed the use of less total herbicide for the third year. In 1991, 9% less total herbicide was applied than the amount prophylactically applied by the farmers. This is important because soil-applied herbicides frequently are being detected in surface and groundwater samples. The model again outperformed the corn grower 70% of the time when gross margin was measured. Presentations to corn growers on the concepts and use of the bioeconomic model were an important component of the 1991 program. A field day at the Windsor corn research site exposed administrators to the significant advances being made in non-chemical weed control research in corn for Colorado. Regional and national interest in this innovative weed control technology has been high. Approximately 80 % of high quality video footage has been taken for development of a 20-minute professional video on the bioeconomic modeling project. More importantly, key corn growers in Colorado are grasping the importance of weed control principals developed through the use of the computer model. In general, when soil weed seed bank has 30 million seed/A or less, a farmer probably can forego the use of a soil-applied herbicide, and obtain satisfactory weed control using mechanical tillage and postemergence herbicides where necessary. Thus, the stage is set for increased technology transfer efforts with the bioeconomic model in the future.

INTERPRETATION: Based on three years of data from 39 farm sites, the model suggests that increased gross margins and reduced herbicide loading can be achieved with the weed management model compared to farmer weed management decisions. The transfer of this technology to the Corn Belt States should lead to reduced herbicide use.

FUTURE PLANS: The fourth year of the pilot test will be continued with 15 corn producers in Colorado. EPA is supporting this project in FY 92. The CRIS will terminated in September 30, 1993.

DECISION AIDS TO MANAGE WEEDS IN CORN AND SOYBEANS IN MINNESOTA

Robb King, Doug Buhler, Bruce Maxwell, and Edward Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-03S
SCA 58-5402-1-116

PROBLEM: The use of herbicides on corn accounts for roughly 40% of all agricultural herbicide use and 25% of agricultural pesticide use, for a total of 200 million pounds over the nation's 70 million acres of field corn. The bioeconomic weed-corn modeling technology developed by ARS and Colorado State University scientists provides many options for corn producers to use to reduce reliance on herbicides. Since this technology is contributing to the Presidential Initiative on Enhancing Water Quality, ARS and EPA wanted this technology adapted for rainfed agriculture.

APPROACH: The Colorado technology was shared with scientists at the University of Minnesota so they could: 1) modify, refine, and upgrade the Colorado technology to reflect local conditions for their corn producers, and 2) build a prototype weed-soybean model. The corn/soybean model (WEEDSIM) was validated in field trials in 1991 and field research on weed/crop interactions and weed population dynamics needed to improve the prediction power of WEEDSIM were undertaken at the Rosemount research center.

FINDINGS: In a corn experiment, herbicide load was reduced from 4.5 lb/A with the standard herbicide to 3.5 lb/A with the seed bank model and to 0.28 lb/A with the seedling count model. Costs for the three herbicide treatments ranged from $25.25 for the standard to $26.80 for the seedling count model. The least expensive treatment was a mechanical system at $14.30/A. In a soybean experiment, herbicide load was reduced from 3.5 lb/A with the standard treatment to 0.75 lb/A with the seed bank model and zero with the seedling count model. The model generated-treatments also reduced weed control costs, but these treatments did not perform well from an agronomic standpoint.

INTERPRETATION: Results from the corn validation experiment were very encouraging and the data will be used to improve and expand the current model. Several problems with the soybean model surfaced. These problems were related to the way the model treated the rotary hoe and the interaction of rotary hoeing with prior herbicide treatment. The model will be adjusted to correct these problems.

FUTURE PLANS: Additional experiments are planned for 1992 to examine the interaction of rotary hoeing with prior herbicide treatment. EPA will fund this project for 1992. Transfer of the WEEDSIM to other corn belt states is being initiated through the activities of NC-202.

IMPROVING WEED CONTROL AND WATER QUALITY WITH TILLAGE AND LESS HERBICIDE

Phillip Westra and Edward E. Schweizer
Water Management Research Unit

CRIS: 0500-00032-021-01S
SCA 58-5402-1-125

PROBLEM: Herbicides accounted for 85 percent of the pesticides applied in 1989. More than 50 percent of the herbicides were applied to corn, double that applied to soybeans, the next highest herbicide-use crop. Any practice that reduces the amount of herbicide applied to corn will improve water quality. Two methods to decrease herbicide use are tillage and reducing the rate of herbicide applied per acre.

APPROACH: Corn will be planted in 1992 in plots maintained since 1981 at the Windsor research farm. Factors and variables that will be investigated include: weed seed banks, herbicide rates, tillage (rotary hoe, flex harrow, standard cultivator, and an in-row cultivator). Information will be collected on weed control, weed management costs (tillage and herbicides), and corn yield to compute gross margins. Non-herbicide cultivation and reduced herbicide rate weed control strategies will be compared to strategies specified by the computer-based weed management corn model.

EXPECTED PRODUCTS IN CY 92: A valuable data base that documents the impact of tillage and reduced herbicide rate weed control strategies on corn production. The acquisition of new knowledge on weed threshold populations and the nature of interactions between weeds, tillage, and reduced herbicide rates to facilitate the development of improved control strategies for corn production systems.

INTERPRETATION: This research is expected to reduce herbicide soil loading, leave more weeds, and decrease gross margin.

FUTURE PLANS: The research will be initiated in the spring of 1992 at the Windsor research farm. If funds are available in FY 93, the study will be repeated.

BIOECONOMIC WEED MANAGEMENT DECISION AIDS FOR BARLEY AND PINTO BEAN PRODUCTION

L. J. Wiles and E. E. Schweizer
Water Management Research Unit

CRIS: 5402-22000-002-00D

PROBLEM: Herbicides are apparently reaching groundwater and surface waters as a result of current crop production practices. Herbicide use can be reduced without compromising net profit through more efficient weed management. We can protect the quality of groundwater and surface waters by helping growers manage weed populations more efficiently.

APPROACH: The objective of this work is to develop bioeconomic weed management decision aids for irrigated barley and pinto bean production. The use of bioeconomic weed management decision aids can increase the efficiency of weed management and reduce herbicide use. These programs can help decision makers match the selectivity of a control treatment to the composition of the anticipated or actual weed population as well as do a cost/benefit analysis to ensure control is used only when the benefits are expected to exceed the costs. A reduction in herbicide use, in comparison to intensive, prophylactic herbicide use, has been documented for the use of two existing programs. While herbicide use was reduced, grower's profit was maintained or increased.

FINDINGS AND INTERPRETATION: Discussions about weed management decision aids with other researchers have revealed the widespread interest in the development of decision aids for a variety of crops and current difficulties in using existing aids for different regions of the country. We are cooperating with researchers at the University of Minnesota to develop our decision aids in a format which will facilitate modification of our model for other regions and other crops, particularly for researchers without programming experience. This cooperation should speed the development of decision aids at both locations and should permit more widespread use of the systems we develop. Our discussions and a review of the literature have also highlighted the lack of essential information about weed seed germination. Developing a realistic model of weed seed germination which captures how this complex process impacts weed management will likely be the most challenging component of this work.

FUTURE PLANS: We should have a prototype pinto bean weed management model ready for preliminary validation this summer. This prototype model will be linked to the database component for altering model inputs and parameters which is currently being developed at the University of Minnesota. Substantial effort will be directed toward developing a model of weed seed germination which we will incorporate into the decision aids. We will continue cooperating with other scientists to locate all available data on weed seed germination and to identify the missing information and potential avenues for obtaining that information.

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